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TENTATIVE REVISIONS OF STANDARDS

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American Society for Testing Materials

ORGANIZED IN 1898
INCORPORATED IN 1902

PROCEEDINGS, PART I

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

The following Summary records the action taken by the Society at the Annual Meeting on the Recommendations Affecting Standards and Tentative Standards appearing in the Annual Reports of the Standing Committees. In the individual committee reports attention is called through an editorial footnote to any modifications of the recommendations or where the recommendations of the committee were not approved. In all other instances it is to be understood that the recommendations were approved as submitted by the committee.

SUMMARY OF PROCEEDINGS OF THE FORTY-FIRST ANNUAL MEETING

Atlantic City, N. J., June 27–July 1, 1938

The Forty-first Annual Meeting of the American Society for Testing Materials was held at Chalfonte-Haddon Hall, Atlantic City, N. J., June 27–July 1, 1938. The following is an analysis of the registered attendance at the meeting: Members in attendance or represented, 819; committee members, 178; guests, 141; total 1138; ladies, 271. The corresponding statistics for the Fortieth Annual Meeting are as follows: Members in attendance or represented, 960; committee members, 186; guests, 377; total, 1523; ladies, 179.

The First A.S.T.M. Photographic Competition and Exhibition was held during the annual meeting. Arrangements for the exhibition were made by a special committee, consisting of M. F. Skinker, chairman, W. Herriott, and G. O. Hiers. The theme of the exhibition photographs this year was limited to those relating to "testing," classified under two groups, the purely amateur class, and the so-called professional class. There were upwards of 75 photographs on display, covering many phases of testing, testing instruments, and the like.[1]

First Session

Tuesday, June 28, 10.30 a. m.

Formal Opening Session

President A. E. White and Past-President T. R. Lawson, co-chairmen.

President White in opening the Forty-first Annual Meeting directed attention to the many accomplishments and advances in materials standardization as evidenced by the large number of recommendations being presented by the committees to the Society this year. Reference was made to the program, replete with interesting technical papers, and the reports on the investigative and cooperative research studies being carried on by the committees, also to the fact that some 225 meetings of committees and their subcommittees were scheduled to be held during the week. He stated that this activity and these accomplishments and contributions were commendable in view of the status of industrial conditions during the past year.

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[1] Further information concerning the Photographic Exhibit and the prize-winning photographs appear in the ASTM Bulletin, No. 93, August, 1938.

The President then introduced P. H. Bates, chairman of Committee E-9 on Research, who presented the report of the committee.

The report of Committee E-10 on Standards, in the absence of the chairman, Cloyd M. Chapman, was presented by the Assistant Secretary.

President White then introduced the Secretary-Treasurer, C. L. Warwick, who presented the report of the Executive Committee. This report on general Society activities covered membership, publications, finances, and administrative matters relating to committee activities and inter-society relations.

President White then called attention to the fact that this was the Fortieth Anniversary of the Society and the Executive Committee had deemed it desirable that appropriate recognition be made of this milestone. He reviewed briefly a number of interesting events that surrounded the organization of the Society beginning with the formation in 1898 of an American Section of the International Association for Testing Materials. The President said that of the original 40 individual and company members who comprised the American Section at its organization in 1898 there were 13 who were still members of the Society and who had maintained their affiliation continuously during the forty-year period. President White then read the names of these 13 members[1] and on behalf of the Executive Committee announced that they would receive certificates commemorating the fact that they have been members of the Society for forty years.

Past-President T. R. Lawson then assumed the chair.

The chairman presented the President, Albert Easton White, who delivered the annual Presidential Address on "Organized Research," in which he pointed out that research is one of the keystones upon which further world progress depends, since it enters into the fields of agriculture, communications, transportation, public health, and the production of industrial products. President White discussed in detail the various agencies engaged in research which included individuals, corporations, associations, testing laboratories, Government bureaus, councils, foundations, societies, research institutes, and colleges and universities. He further stated that there is a definite interlocking of all of these groups and that each one is dependent for its prosperity and advancement upon the others. In referring to the fact that research is the backbone of standardization, President White emphasized the importance of the Society's research activities on properties of materials and methods of testing. He pointed out that this work has contributed materially to the advancement of knowledge of engineering materials and resulted in the establishment of many industrial standards. In concluding his presidential address, President White expressed the opinion that sponsorship of both fundamental and applied research must be continued at an ever-accelerating rate. He recommended that every encouragement should be given to those individuals and agencies engaged in research so that, through their achievements, research may contribute its share in restoring prosperity, improving standards of living, and adding to our store of cultural values.

For the Award of Honorary Membership, Past-President Lawson requested G. H. Clamer to escort Frank O.

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[1] The list of forty-year members appears in the ASTM BULLETIN, No. 93, August, 1938, p. 9.

Clements to the platform, P. H. Bates to escort William K. Hatt, and F. E. Richart to escort Herbert F. Moore. Each in turn was presented to the President who made the award of the Honorary Membership Certificate on behalf of the Executive Committee which had unanimously elected them as Honorary Members in recognition of the eminent position each had attained in the field of materials testing and in acknowledgment of the many years of service given in the cause of engineering standardization.

The chairman then recognized J. S. Miller, chairman of the Committee of Tellers, who reported the results of the letter ballot on election of officers. Of the 1210 ballots cast, the results were as follows:

For President, to serve for one year:
T. G. Delbridge, 1196 votes.
For Vice-President, to serve for two years: W. M. Barr, 1197 votes.
For members of the Executive Committee, to serve for two years:
A. T. Goldbeck, 1184 votes.
Dean Harvey, 1182 votes.
G. E. Hopkins, 1176 votes.
Allen Rogers, 1180 votes.
J. J. Shuman, 1174 votes.

In accordance with the ballot the chair declared the officers listed above elected.

The chairman then introduced the newly elected members of the Executive Committee.

At the request of the chairman, Past-President H. S. Vassar escorted to the chair the Vice-President-Elect, W. M. Barr, who, in expressing appreciation of the honor bestowed upon him in his election, stated that he has valued his associations with the Society and considers it a privilege to serve the Society in this capacity.

The chairman requested Past-President K. G. Mackenzie to escort to the chair the President-Elect, T. G. Delbridge, who, in expressing sincere appreciation of the honor of his election to the presidency, stated that he realized the obligations entailed and that he would make every effort to administer satisfactorily the affairs of the Society during the coming year.

The meeting then adjourned till 2 p. m.

SECOND SESSION

Tuesday, June 28, 2 p. m.

Water

Messrs. J. H. Walker and J. B. Young, co-chairmen.

The report of Committee D-19 on Water for Industrial Uses was presented by the chairman, Max Hecht. The new Methods of Sampling Plant or Confined Waters for Industrial Uses, for the Determination of Calcium Ion and Magnesium Ion in Industrial Water, of Chloride Ion in Industrial Water, of Total Carbon Dioxide and Calculation of Carbonate and Bicarbonate Ions in Industrial Water, of Hydroxide Ion in Industrial Water, of Total Orthophosphate and Calculations of the Respective Orthophosphate Ions in Industrial Water, and of Sulfate Ion in Industrial Water were accepted for publication as tentative.

The following papers were then presented and discussed:

"The Estimation of Sodium in Water Supplies by an Indirect Method," by J. B. Romer, W. W. Cerna, and H. F. Hannum, presented by Mr. Romer.

"Removal of Dissolved Salts from Water by Exchange Filters," by P. G. Bird, presented by the author.

A progress report of the Joint Research Committee on Boiler Feedwater Studies[1] was presented from manuscript by the chairman, C. H. Fellows.

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[1] Published in ASTM BULLETIN, No. 93, August, 1938, p. 32.

A paper entitled "A Method for the Embrittlement Testing of Boiler Waters," by Frederick G. Straub and T. A. Bradbury, was presented by Mr. Straub and discussed.

The meeting then adjourned till 8 p. m.

THIRD AND FOURTH SESSIONS

Tuesday, June 28, 2 p. m., and 8 p. m.

Symposium on Impact Testing

President A. E. White and Mr. M. F. Sayre, co-chairmen.

President White, in opening the Symposium on Impact Testing, presented Mr. Sayre who presided during the first part of the symposium.

Mr. Sayre, in introducing the symposium stated that it had been arranged jointly by the American Society for Testing Materials and The Engineering Foundation's Welding Research Committee, which is sponsored by The American Welding Society and the American Institute of Electrical Engineers. He stated that the symposium comprised a series of nine papers to be presented in two groups of four each, and would include an integrated series of individual contributions covering the basic theories underlying impact tests, data on the factors affecting impact, the practical application of impact tests to metals, organic plastics, and welds. Mr. Sayre pointed out that the impact problem consists of three related effects: (1) shape or notch effects, (2) velocity effects, and (3) temperature effects, and that each of these effects would be discussed from the standpoint of homogeneous materials and also for welds, and a treatment of the basic theory underlying all three. Mr. Sayre also stated that the symposium was intended to make available to the testing public an authoritative and critical review of present knowledge on impact failures and methods of test.

The first group of papers was then presented as follows and discussed:

"Utility and Non-Standard Impact Testing," by Sam Tour, presented by the author.

"The Impact Testing of Plastics" (illustrated with motion pictures), by Robert Burns and Walter W. Werring, presented by Mr. Burns.

"Practical Application of the Notched-Bar Impact Test," by G. C. Riegel and F. F. Vaughn, presented by Mr. Riegel.

"The Use of the Charpy Test as a Method of Evaluating Toughness Adjacent to Welds," by Walter H. Bruckner, presented by the author.

President A. E. White and Mr. W. W. Werring, co-chairmen.

President White in opening the second part of the symposium presented Mr. Werring who presided during the presentation of the following papers, each of which was discussed:

"Stress-Strain Relations Under Tension Impact Loading," by D. S. Clark and G. Dätwyler, presented by Mr. Clark.

"The Theory of Impact Testing: Influence of Temperature, Velocity of Deformation, and Form and Size of Specimen on Work of Deformation," by D. J. McAdam, Jr. and R. W. Clyne, presented by Mr. McAdam.

"Some Considerations on the Impact-Testing Problem," by N. Davidenkoff (of U.S.S.R.), presented from manuscript by Mr. Sayre.

"Impact Tests of Welded Joints—II: A Review of the Literature from January 1, 1936, to January 1, 1938," by W. Spraragen and G. E. Claussen, presented from manuscript by Mr. Spraragen.

"Notched-Bar Testing and Impact Testing," by S. L. Hoyt, presented from manuscript by the author.

The meeting then adjourned till the following morning.

FIFTH SESSION

Wednesday, June 29, 9.30 a. m.

Radiography

Messrs. J. H. Hall and G. F. Jenks, co-chairmen.

The report of Committee E-7 on Radiographic Testing was presented from manuscript by the chairman, H. H. Lester.

The following papers were then presented and discussed:

"Radiography in Industry,"[1] by H. H. Lester, presented from manuscript by the author.

"Secondary Radiation in the Radiography of Aluminum, Steel and Lead," by Herman E. Seemann, presented from manuscript by the author.

"Gamma-Ray Radiography," by Gilbert E. Doan and Shang-Shoa Young, presented by Mr. Doan.

"A Study of Intensifying Screens for Gamma-Ray Radiography," by Charles W. Briggs and Roy A. Gezelius, presented by Mr. Briggs.

The meeting then adjourned till 1.45 p. m.

SIXTH SESSION

Wednesday, June 29, 9.30 a. m.

Concrete and Concrete Aggregates

Messrs. F. E. Richart and Stanton Walker, co-chairmen.

The report of Committee C-9 on Concrete and Concrete Aggregates was presented by the chairman, R. W. Crum. The new Methods of Test for Determination of Yield of Concrete, and Test for Soundness of Aggregates by Freezing and Thawing were accepted for publication as tentative.

The new Method of Test for Sieve Analysis of Fine and Coarse Aggregates, presented jointly by Committee C-9 and Committee D-4 on Road and Paving Materials, was accepted for publication as tentative to replace four existing standard methods. The withdrawal of the Standard Methods of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 18 – 16), of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 19 – 16), of Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete (D 7 – 27), and of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 36) was approved.

The Tentative Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Third Point Loading (C 78 – 36 T), and Method of Test for Flow of Portland-Cement Concrete by Use of the Flow Table (C 124 – 36 T) were approved for reference to letter ballot of the Society for adoption as standard.

The tentative revisions of the Standard Method of Making and Storing Compression Test Specimens of Concrete in the Field (C 31 – 33), and Specifications for Ready Mixed Concrete (C 94 – 35) were approved for reference to letter ballot of the Society for adoption as standard.

The recommendation presented on the floor at the annual meeting that the tentative revisions[2] of the Standard Specifications for Curing Portland-Cement Concrete Slabs with Calcium Chloride Admixture (C 82 – 34) and for Curing Portland-Cement Concrete Slabs by Surface Application of Calcium Chloride (C 83 – 36) be adopted was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote, subject to favorable letter ballot of Committee C-9.[1]

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[1] Published in ASTM BULLETIN, No. 94, October, 1938, p. 5.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1312, 1313 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1570, 1571.

It was announced that the committee had completed the preparation of a new Method of Test for Clay Lumps in Aggregate, and proposed revisions of the Tentative Methods of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131 – 37 T), Test for Unit Weight of Aggregate for Concrete (C 29 – 27), and Test for Structural Strength of Fine Aggregate Using Constant Water-Cement-Ratio Mortar (C 87 – 36) which, after approval by letter ballot of the committee, will be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

In presenting the report Mr. Crum called upon Charles E. Wuerpel to present from manuscript his paper entitled "Factors Affecting the Testing of Concrete Aggregate Durability," which is to be appended to the C-9 report. The paper was then discussed. Mr. Crum then presented the paper entitled "Stress-Strain Characteristics of Mortars and Concretes," by H. J. Gilkey and Glenn Murphy, appended to the report, which was discussed.

The following papers were then presented and discussed:

"Drying Shrinkage of Concrete as Affected by Many Factors," by Roy W. Carlson, presented by the author.

"Short-Time Creep Tests of Concrete in Compression," by Russell S. Jensen and Frank E. Richart, presented by Mr. Richart.

"A Study of Fine Aggregate in Freshly Mixed Mortars and Concretes," by C. A. G. Weymouth, presented from manuscript by T. C. Powers.

The meeting then adjourned till 1.45 p. m.

SEVENTH SESSION

Wednesday, June 29, 1.45 p. m.

Methods of Testing, Timber, Electrical-Heating Alloys

Mr. R. L. Templin and Past-President H. S. Vassar, co-chairmen.

The report of Committee E-4 on Metallography was presented by the chairman, J. T. Norton. In presenting the report Mr. Norton called on L. L. Wyman to present his paper entitled "The Plastics for Mounting of Metallographic Samples," which appeared as an appendix to the report.

A paper entitled "The Examination of Metals in Polarized Light," by L. V. Foster and J. E. Wilson, was presented by Mr. Foster.

The report of Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys was presented by the chairman, Dean Harvey. The new Method of Test for Temperature-Resistance Constants of Sheet Materials for Shunts and Precision Resistors was accepted for publication as tentative.

The new Method for Bend Testing of Wire (Wire for Radio Tubes and Incandescent Lamps), with the following changes presented on the floor at the annual meeting subject to favorable letter ballot of Committee B-4,[1] was accepted for publication as tentative:

Section 1.—Change from the form as preprinted to read as follows by the omission of the words in brackets and the addition of a footnote:

1. This method of test is intended to evaluate the "temper" of wire for radio tubes,

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[1] These recommendations were submitted to letter ballot of Committee C-9, which consists of 61 members; 37 members returned their ballots, of whom 28 voted affirmatively and 1 negatively.

incandescent lamps and electrical resistances purposes [in terms of the energy expended in producing a given amount of bending]. It is intended for use on wire from approximately 0.010 to 0.117 in. (0.25 to 3.0 mm. in diameter.[a]

Section 2.—Change the first sentence from the form as preprinted to read as follows by the addition of the italicized words and the omission of those in brackets:

> The test comprises clamping a specimen of wire rigidly at one end, subjecting it to a bending force and measuring the *angle of bend* [energy absorbed by the specimen per unit of bending].

Change the last sentence of the section as preprinted, to appear as a note.

Section 3.—Change Paragraph (*d*) from the form as preprinted to read as follows by the omission of the words in brackets:

> (*d*) [Adjustable counterweights with motions at 90 deg. to each other or other] Means for ensuring that when the loading system is in its initial position ready for making a test its center of gravity will lie within plus or minus 1 deg. of the horizontal plane passing through the axis of rotation.

Delete the first sentence of Paragraph (*e*), as preprinted, which reads as follows:

> The speed of bending may in some cases have a slight effect on the amount of energy absorbed by the specimen.

Change Paragraph (*g*) from the form as preprinted to read as follows by the omission of the words in brackets:

> (*g*) Means for measuring the angular position and range of motion of the loading system [and hence the energy expended] in bending the specimen.

Change Paragraph (*k*) from the form as preprinted to read as follows by the addition of the italicized figures and the omission of those in brackets:

> (*k*) Means for leveling the apparatus within *1.0* [0.25] deg.

Section 6.—Change Paragraph (*a*) from the form as preprinted to read as follows by the addition of the italicized figures and the omission of those in brackets:

> 6. (*a*) Leveling the Machine.—The machine shall be leveled to bring the plane passing through the axis of rotation and the center of gravity of the weighted loading system to within *1.0* [0.25] deg. of the horizontal when the latter is in the initial position.

Change Paragraph (*b*) from the form as preprinted: namely,

> (*b*) *Balancing the Carrier.*—The bending die shall be set at the required position. Horizontal balance shall be obtained by adjustment of the counter weight, tapping the instrument lightly to increase the sensitivity. Then, with the carrier at about 35 deg. below the horizontal, repeat the tapping and adjust the counterweights until vertical balance is obtained.

to read as follows:

> (*b*) *Balancing the Carrier.*—The bending die shall be set at the required position. The loading weights shall be removed. Tapping the machine lightly to minimize the effects of bearing friction, the carrier shall be adjusted to balance in both the horizontal position and at about 35 deg. below the horizontal.

Change the first and second sentences of Paragraph (*c*) from the form as preprinted to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*c*) Checking for Friction.—The *carrier* [loading system] shall be weighted to provide an initial turning moment of 5 cm-g. When released without a specimen in place it shall rotate steadily through an angle of not less than *40* [45] deg.

Change Paragraph (*e*) from the form as preprinted to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*e*) Setting of Bending Die.—The bending die shall be adjusted on the carrier so that the center line of the surface of the former which makes contact with the specimen is distant from the axis of rotation of the specimen clamp by *a fixed distance of 0.197 in. (5 mm.), 0.394 in. (1 cm.), 0.688 in. (2 cm.), or 1.376 in. (4 cm.) as may be agreed upon* [15 D ± 0.005 in., where D is the diameter

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[a] An investigation is being made to determine whether a correlation can be found between this method and other bend test methods, such as Methods A and C as outlined in the Appendix to the 1936 Annual Report of Committee B-4.

of the wire to be tested] (see Fig. 2). This distance is the bending radius.

Change the last sentence of Paragraph (*f*) from the form as preprinted: namely,

> Electrical means such as a miniature lamp bulb and battery may be used to indicate contact between the specimen and the bending die.

to read as follows:

> Means shall be provided and used to indicate contact between the specimen and the bending die.

Change the second sentence of Paragraph (*g*) as preprinted to read as follows by the addition of the italicized words and the omission of those in brackets:

> The weighting shall be *as agreed upon for the material under test and shall give* [adjusted by trial on successive specimens until a setting is obtained which gives] a net movement of the loading system of approximately 30 deg. [or such other angle as may be agreed upon.]

In the note following Paragraph (*g*) change the phrase "energy absorption is most sensitive" to read "test is most sensitive."

The revision proposed for immediate adoption in the Standard Accelerated Life Test for Metallic Materials for Electrical Heating (B 76 – 36) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

It was announced that the committee had decided to withdraw the Proposed Methods of Testing Nickel and Nickel Alloy Electronic Tube Filaments, which appeared in the report as preprinted. The Proposed Method of Testing Cathode Sleeves and Cathode Tubing was accepted for publication as information.

The report of Committee E-1 on Methods of Testing was presented by the chairman, W. H. Fulweiler, who called upon H. F. Moore to describe the activities of Technical Committee I on Mechanical Testing, on L. T. Work to report on the work of Technical Committee III on Particle Size and Shape, and on H. F. Dodge to describe the activities of Technical Committee IX on Interpretation and Presentation of Data and Technical Committee XI on Designation and Interpretation of Numerical Requirements.

It was announced by Mr. Moore that Technical Committee I had completed certain revisions in the Tentative Method of Bend Testing for Ductility of Metals (E 16 – 31 T), which after approval by letter ballot of Committee E-1 would be submitted to the Society through Committee E-10 on Standards subsequent to the annual meeting. Mr. Work also announced that Technical Committee III had approved for submission to letter ballot revised specifications for sieves for testing purposes, prepared by Sectional Committee Z23, which, after approval by letter ballot of Committee E-1 would be submitted to the Society through Committee E-10 on Standards subsequent to the annual meeting to replace immediately the existing Standard Specifications for Sieves for Testing Purposes (E 11 – 26), and for Round-Hole Screens for Testing Purposes (E 17 – 36).

In concluding the report Mr. Fulweiler called on Mr. Wilhelm to present from manuscript the paper entitled "Methods of Testing Thermometers," by E. F. Mueller and R. M. Wilhelm.

The following papers were then presented:

"Statistical Methods as an Aid in Revising Specifications," by N. C. Wiley, presented by the author and discussed.

"A Level-Bubble Strain Gage,"[1] by Rex L. Brown, presented by T. J. Dolan.

An informal report of Sectional Committee Z23 on Specifications for Sieves for Testing Purposes was presented from manuscript by the chairman, Lincoln T. Work.

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[1] Published in ASTM BULLETIN, No. 93, August, 1938, p. 16.

The report of Committee D-7 on Timber was presented by the chair. The proposed revision of the Tentative Method of Test for Tar Acids in Creosote and Creosote - Coal Tar Solutions (D 453 - 37 T) was accepted, the method as revised being continued as tentative.

The meeting then adjourned till 4.15 p. m.

EIGHTH SESSION

Wednesday, June 29, 4.15 p. m.

Edgar Marburg Lecture

President A. E. White in the chair.

President White in opening the session devoted to the Edgar Marburg Lecture recalled the establishment of this memorial Lecture 12 years ago to perpetuate the memory of the first Secretary-Treasurer of the Society, Edgar Marburg. The Lecture brings to the Society through authorities in engineering and the sciences valuable descriptions of outstanding developments in the engineering materials field. It also commemorates one whose ideals, vision and foresight at the time of organization of the Society has made it the forum for expositions contributing to the furthering of knowledge of engineering materials.

The President then introduced the thirteenth Edgar Marburg Lecturer, Dr. Albert Sauveur, Metallurgical Engineer, and Professor Emeritus, Harvard University, who had selected as the subject of the lecture "The Torsion Test." Doctor Sauveur referred to the wide use of the tension test and stated that since faith in it has been so deeply rooted, it is considered one of the most satisfactory methods for the selection of materials and their useful application to many needs. He pointed out that all we can reasonably expect of a test method is that it enlighten us as to the properties of the materials tested, so that they may be used more intelligently, with greater economy and greater safety. The aim of the investigations described in the lecture was to discover whether the torsion test was a simple and satisfactory method of ascertaining the properties of metals. Doctor Sauveur described briefly the machine, mentioning that it was capable of testing at very slow and quite rapid speeds, and the types of test specimens used which were of reduced section and machined from solid bars. Considerable data were included in the paper on various materials tested. Some of the tests were conducted in the blue heat range and Doctor Sauveur also discussed torsion testing at elevated temperatures and studies of reverse twisting. He pointed out that there is little doubt but that useful information could be obtained from a closer study of the significance of the hysteresis loops. He stated that a close relation must exist between them and the physical properties of metals which is not readily brought out by the tension test. Reverse twisting seemed to afford an excellent and simple method of studying the effect of cold work.

Doctor Sauveur also presented results of studies on single crystals of copper of high purity when subjected to torsion and in this connection he said, speculating, it might be conceived that twisting in the plastic range takes place by block slipping and that in the case of polycrystalline metal and also in single crystals fragmented by deformation the slipping blocks are so small that the individual steps are not recorded on the curve. In conclusion Doctor Sauveur outlined certain claims for the torsion test, as follows: (1) simplicity of manipulation, (2) low cost of torsion testing machine, (3) low cost of preparation of test bars, (4) adaptability to high-temperature testing, (5) possibility of reverse twisting, (6) possible adaptability to determination of creep, (7) possibility of testing at will under constant speed of twisting or under constant speed of loading, (8) determination of properties unrevealed by the tension test.

President White, in expressing appreciation to Doctor Sauveur for his interesting and instructive lecture on a subject of particular interest to the Society, presented to him, on behalf of the Society, the Edgar Marburg Lecture Certificate.

President White then recognized E. F. Kelley, chairman of the Committee on Award of the Charles B. Dudley Medal. Mr. Kelley presented as the recipient of the 1938 Award of the Dudley Medal Mr. R. H. Heyer, Member of the Research Department, the American Rolling Mill Co., for his paper on "Analysis of the Brinell Hardness Test," presented at the 1937 annual meeting of the Society, and considered by the committee as a paper of outstanding merit, constituting an original contribution on research in engineering materials testing.

On behalf of and as the representative of the Society, President White then made the twelfth award of the Charles B. Dudley Medal to Mr. Heyer.

In accepting the medal Mr. Heyer expressed sincere appreciation of the honor conferred upon him by the award.

The meeting then adjourned till 8 p. m.

NINTH SESSION

Wednesday, June 29, 8 p. m.

Cement and Concrete

Messrs. J. C. Pearson and H. F. Clemmer, co-chairmen.

The report of Committee C-13 on Concrete Pipe was presented by the chairman, E. F. Kelley. The proposed revision of the Tentative Specifications for Concrete Irrigation Pipe (C 118 - 35 T) was accepted, the specifications as revised being continued as tentative. The withdrawal of the tentative revision of the Standard Specifications for Concrete Sewer Pipe (C 14 - 35) was approved.

An informal report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete was presented by the chairman, A. E. Lindau.

The following papers were then presented and discussed:

"Some Factors Influencing the Bond Between Concrete and Reinforcing Steel," by Raymond E. Davis, Elwood H. Brown and J. W. Kelly, presented by Mr. Davis.

"Measuring Young's Modulus of Elasticity by Means of Sonic Vibrations," by T. C. Powers, presented by the author.

The report of Committee C-1 on Cement was presented by the chairman, P. H. Bates, who announced that a report of the Subcommittee on Tests of Additions to Cement had been received and would be included in the report as finally published. The proposed revisions of the Tentative Specifications and Tests for Masonry Cement (C 91 - 32 T), Methods of Chemical Analysis of Portland Cement (C 114 - 37 T) (new quick methods for determining manganic oxide, for determining potassium oxide and sodium oxide, and for determining water-soluble alkali in cement), and Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 - 34 T) were accepted, the specifications and methods as revised being continued as tentative.

The revisions proposed for immediate adoption in the Standard Specifications for Portland Cement (C 9 - 37), and for High-Early-Strength Portland Cement (C 74 - 36) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote. Sections 1 to 4 of the Tentative Method of Chemical Analysis of Portland Cement (C 114 – 37 T) were approved for reference to letter ballot of the Society for adoption as standard.

The following papers were then presented and discussed:

"The Effect of Using a Blend of Portland and Natural Cement on Physical Properties of Mortar and Concrete," by W. F. Kellermann and D. G. Runner, presented by Mr. Kellermann.

"Studies of the Operation of the Wagner Turbidimeter," by H. S. Ponzer and D. R. MacPherson, presented by Mr. Ponzer.

The meeting then adjourned till the following morning.

TENTH SESSION

Wednesday, June 29, 8 p. m.

Effect of Temperature, Fatigue of Metals

Messrs. H. S. Rawdon and Sabin Crocker, co-chairmen.

The report of the Joint Research Committee on Effect of Temperature on the Properties of Metals was presented by the chairman, H. J. French, who called upon the individuals indicated below to present the following appendices:

Progress Report on Creep Tests of Tubular Members Subjected to Internal Pressure, prepared by F. H. Norton, presented by the author.

Report on Long-Time Creep Test of 0.35 per cent Carbon Steel (K20), prepared by Howard C. Cross and J. G. Lowther, presented by Mr. Cross.

Report Covering Creep Tests on 0.35 per cent Carbon Steel (K20) at 850 F. Under a Stress of 7500 lb. per sq. in., prepared by C. L. Clark, presented by the author.

Report of Acceptability Tests for High - Temperature Characteristics, prepared by A. E. White and C. L. Clark, presented by Mr. Clark.

Progress Report on Study of Effects of Manufacturing Variables on the Creep Resistance of Steels, prepared by Howard C. Cross and J. G. Lowther, presented by Mr. Cross, and discussed.

The proposed revision of the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 – 35 T), presented by C. L. Clark, was accepted, the method as revised being continued as tentative.

In concluding the report, Mr. French called attention to the Report Covering Information on Steels for Tubular Creep Tests and Other Test Work of the Joint Committee, prepared by H. J. Kerr, J. B. Romer, and H. D. Newell, also appended to the report.

A paper entitled "Actual Grain Size Related to Creep Strength of Steels at Elevated Temperatures," by S. H. Weaver, was presented by the author and discussed.

The report of the Research Committee on Fatigue of Metals was presented by the chairman, H. F. Moore.

The following papers were then presented:

"The Effect of Overstressing and Understressing in Fatigue," by J. B. Kommers, presented by H. F. Moore and discussed.

"An Investigation of the Effects of Elevated Temperatures on the Fatigue Properties of Two Alloy Steels," by J. S. Kinney, presented by the author.

"Recent Developments in European Research on Fatigue of Metals,"[1] by Richard P. Seelig, presented from manuscript by the author and discussed.

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[1] Published in the ASTM BULLETIN, No. 94, October, 1938, p. 23; No. 95, December, 1938, p. 15.

The meeting then adjourned till the following morning.

ELEVENTH SESSION

Thursday, June 30, 9.30 a. m.

Steel, Ferro-Alloys, Corrosion

Messrs. W. M. Barr and O. U. Cook, co-chairmen.

The report of Committee A-9 on Ferro-Alloys was presented by the chairman, Charles McKnight. It was announced that the committee had completed the preparation of revisions in the Standard Specifications for Spiegeleisen (A 98 – 27), for Ferromanganese (A 99 – 27), for Ferrosilicon (A 100 – 27), for Ferrochromium (A 101 – 27), for Ferrovanadium (A 102 – 27), for Molybdenum Salts and Compounds (A 146 – 34), for Ferromolybdenum (A 132 – 34), for Low-Carbon Ferromolybdenum (A 145 – 34), and for Ferrotungsten (A 144 – 34), each in the form of separate tentative specifications which, after approval by letter ballot of the committee, would be submitted to the Society for publication through Committee E-10 on Standards subsequent to the annual meeting.

The report of Committee A-1 on Steel was presented by the chairman, H. H. Morgan.

The new Specifications for Normalized Quenched - and - Tempered Alloy - Steel Forgings were accepted for publication as a tentative revision of the present Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts and Other Forgings for Locomotives and Cars (A 63 – 36).

The proposed revisions of the Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 37 T), for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T), and for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A 194 – 36 T) were accepted, the specifications as revised being continued as tentative.

The proposed revisions of the Standard Specifications for Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 – 36), for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 36), for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 36), for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F. (A 182 – 36), and for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33) were accepted for publication as tentative.

It was announced that the committee had decided to withdraw from its report as preprinted the proposed revisions of the Tentative Specifications for Seamless Steel Boiler Tubes for High-Pressure Service (A 192 – 36 T) and of the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 36) since further revisions in both of these specifications were contemplated for submission to the Society through Committee E-10 on Standards subsequent to the annual meeting.

The Tentative Specifications for Structural Nickel Steel (A 8 – 36 T), for Seamless Cold-Drawn Alloy-Steel (4 to 6 per cent Chromium) Heat-Exchanger and Condenser Tubes (A 187 – 36 T), for Seamless Alloy-Steel (4 to 6 per cent Chromium) Still Tubes for Refinery Service (A 188 – 36 T), for Carbon-Silicon-Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (A 201 – 37 T), for Chrome-Manganese-Silicon (CMS) Alloy-Steel Plates for Boilers and Other

Pressure Vessels (A 202 – 37 T), for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204 – 37 T) (with editorial changes), and for Cold-Rolled Strip Steel (A 109 – 35 T) were approved for reference to letter ballot of the Society for adoption as standard.

The tentative revisions of the Standard Specifications for Structural Rivet Steel (A 141 – 36), for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 – 36) (with editorial changes), for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates over 2 in. to 4 in., Inclusive, in Thickness) (A 150 – 36) (with editorial changes), and for Boiler and Firebox Steel for Locomotives (A 30 – 33) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

It was announced that the committee had completed the preparation of new Specifications for Seamless Medium-Carbon Steel Boiler and Superheater Tubes, and for Carbon-Molybdneum Alloy-Steel Boiler and Superheater Tubes which, after approval by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "Physical Properties of Four Low-Alloy High-Strength Steels," by W. L. Collins and T. J. Dolan, was presented by Mr. Collins and discussed.

The report of Sectional Committee B36 on Standardization of Dimensions and Material of Wrought-Iron and Wrought-Steel Pipe and Tubing was presented by the chairman, H. H. Morgan.

The report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys was presented by the chairman, Jerome Strauss.

The proposed revision of the Tentative Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate), (A 167 – 35 T) was unanimously accepted with the following additional modifications, presented on the floor at the annual meeting, which had been approved by letter ballot of the committee but did not appear in the report as preprinted:

Section 4.—Change the table of chemical composition requirements appearing in this section from its present form to read as shown in the accompanying Table I.

TABLE I.—CHEMICAL REQUIREMENTS.

	Type Number	Carbon, per cent	Manganese, max., per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, per cent	Chromium, min., per cent	Nickel, min., per cent
Grade 1	302	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	17.50	8.00
Grade 2	304	0.08 max.	1.50	0.035	0.030	0.75 max.	17.50	8.00
Grade 3	305	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	18.00	9.00
Grade 4	306	0.08 max.	1.50	0.035	0.030	0.75 max.	18.00	9.00
Grade 5[a]	321	0.10 max.	1.50	0.035	0.030	0.75 max.	17.00	8.00
Grade 6[b]	316	0.08 max.	2.00	0.035	0.030	0.75 max.	16.00	10.00
Grade 7	309	0.20 max.	1.50	0.035	0.030	3.50 max.	12.00	12.00
Grade 8	310	0.25 max.	1.50	0.035	0.030	2.00 max.	22.00	19.00
Grade 9[c]	347	0.10 max.	1.50	0.035	0.030	0.75 max.	17.00	8.00
Grade 10	302—B	0.08 to 0.20[d]	1.50	0.035	0.030	2.00 min.	17.50	8.00
Grade 11	301—X	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	16.00	7.00

[a] Grade 5 shall have a minimum titanium content of four times the carbon content.

[b] Grade 6 shall have a molybdenum content of 2.00 to 4.00 per cent.

[c] Grade 9 shall have a minimum columbium content of ten times the carbon content.

[d] The carbon content may be specified 0.12 per cent, maximum, for Grades 1, 3, 10, and 11.

Section 14.—Change this section to read as follows by the omission of the words in brackets:

> 14. The various types of finish procurable on strip products shall be as follows:
>
> (*a*) *Cold-Rolled Strip:*
>
> No. 1. Annealed and pickled.
> No. 2. Annealed, pickled, and rerolled.
> [No. 3. Annealed, pickled, mechanically cleaned or buffed without the use of abrasives.]
>
> (*b*) *Hot-Rolled Strip:*
>
> No. 1. Hot rolled, annealed, and pickled.
>
> *Explanation of Finish:*
>
> No. 1. For parts requiring maximum amount of deep drawing, for oxidation resistance.
>
> No. 2. Slightly harder temper than No. 1 [or No. 3] finish due to extra cold rolling. Very good surface.
>
> [No. 3. For parts requiring medium amount of deep drawing, for rolling and molding operations. This strip has a bright surface and requires very little polishing to finish.]

The Tentative Specifications for Corrosion-Resisting Chromium Steels (Sheet, Strip and Plate) (A 176 – 35 T), and for High-Strength Corrosion-Resisting Chromium-Nickel Steels (Sheet and Strip) (A 177 – 35 T) were approved for reference to letter ballot of the Society for adoption as standard.

A paper entitled "Surface Cracks on Large 18 per cent Chromium, 8 per cent Nickel Alloy Steel Castings,"[1] by Peter R. Kosting, was presented by the author and discussed.

The report of Committee A-5 on Corrosion of Iron and Steel was presented by W. H. Finkeldey.

The new Method of Test for Uniformity of Coating by the Copper Sulfate Dip Test (Preece Test) on Zinc-Coated (Hot-Galvanized) Steel Castings and Forgings, Gray-Iron and Malleable-Iron Castings was accepted for publication as tentative.

The proposed tentative revision of the Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 – 27), in the form of separate tentative specifications, was accepted with the following two additional changes presented on the floor at the annual meeting subject to favorable letter ballot of Committee A-5:[2]

Section 1.—Add to this section the following note:

> NOTE.—These specifications cover zinc-coated (galvanized) sheets for general use. It may be that a series of specifications each covering galvanized sheets for a specific purpose would be more useful. The committee desires particularly to obtain comments on this point.

Section 9.—Add to this section the following footnote:

> If desired, the three test specimens for the triple spot tests on sheets for culverts may be cut from either end of each test sheet, one being cut from the middle of the width of the sheet and the others from the sides and 4 in. from the ends.

The Tentative Method of Test for Uniformity of Coating by the Preece Test (Copper Sulfate Dip) on Zinc-Coated (Galvanized) Iron or Steel Wire (A 191 – 36 T), as revised, was approved for reference to letter ballot of the Society for adoption as standard.

In presenting the report Mr. Finkeldey called upon R. F. Passano to present the report of Subcommittee VIII on Field Tests of Metallic Coatings.

It was announced that the committee had completed revisions in the Tentative Specifications for Electrodeposited Coatings of Zinc or Steel (A 164 – 35 T) of Cadmium on Steel (A 165 – 35 T), and of Nickel and Chromium on Steel (A 166 – 35 T), which, after approval by letter ballot of the committee, would be submitted to the Society through Committee E-10 on Standards subsequent to the annual meeting.

The report of Committee A-6 on Magnetic Properties was presented by the chairman, Thomas Spooner.

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[1] Published in ASTM BULLETIN, No. 93, August, 1938, p. 17.

[2] This recommendation was submitted to letter ballot of Committee A-5, which consists of 100 members; 97 members returned their ballots, of whom 91 voted affirmatively and 0 negatively.

The new Method of Test for Measuring Interlamination Resistance of Steel (A 34 – 38 T), was accepted for publication as tentative, to be added, when adopted, to the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 36).

The revision proposed for immediate adoption in the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 36) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed revision of the Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 36) was accepted for publication as tentative.

The meeting then adjourned till 2 p. m.

TWELFTH SESSION

Thursday, June 30, 9.30 a. m.

Bituminous Materials, Road Materials, Soils

Vice-President T. G. Delbridge and Mr. R. W. Crum, co-chairmen.

The report of Committee D-4 on Road and Paving Materials was presented by the chairman, F. C. Lang. The new Method of Test for Sieve Analysis of Fine and Coarse Aggregates, presented jointly by Committee D-4 and Committee C-9 on Concrete and Concrete Aggregates was accepted for publication as tentative to replace four existing standard methods, issued under the designations D 18 – 16, D 19 – 16, D 7 – 27, and C 41 – 36.

The new Specifications for Crushed Stone for Waterbound Base and Surface Courses (to replace Specifications D 190 – 29 T and D 191 – 29), for Crushed Slag for Waterbound Base and Surface Courses (to replace Specifications D 65 – 23 and D 66 – 23), for Crushed Stone for Bituminous Macadam Base and Surface Courses (to replace Specifications D 192 – 29), for Crushed Slag for Bituminous Macadam Base and Surface Courses (to replace Specifications D 195 – 27 and D 159 – 27), for Crushed Stone for Bituminous Concrete Base and Surface Courses (to replace Specifications D 193 – 29 T and D 194 – 29), and for Crushed Slag for Bituminous Concrete Base and Surface Courses (to replace Specifications D 196 – 27, D 161 – 27 and D 160 – 27) were accepted for publication as tentative.

It was announced that the committee had decided to combine into a single tentative specification the separate specifications for low-consistency tar, medium-consistency tar, heavy-consistency tar, extra-heavy consistency tar, and for cut-back tar, which appeared in the report as preprinted. The new consolidated specifications for tar were accepted for publication as tentative to replace eight existing tentative specifications for tar, issued under the designations D 104 – 36 T, D 105 – 36 T, D 106 – 28 T, D 107 – 28 T, D 108 – 36 T, D 109 – 36 T, D 110 – 36 T and D 111 – 36 T.

The proposed revision of the Standard Method of Test for Ductility of Bituminous Materials (D 113 – 35) was accepted for publication as tentative.

The revision proposed for immediate adoption in the Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 24) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The following modification in the Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for

Use as Highway Materials (Including Some Material Survey Methods) (D 75 - 22), presented on the floor at the annual meeting, was accepted as an editorial change since it is intended at bring the existing methods of sampling into conformity with recently adopted methods of test:

Section 8 (a).—Change from its present form: namely,

> 8. (*a*) The sample of crushed stone for mechanical analysis shall weigh at least 50 times the weight of the largest piece therein.

to read as follows:

> 8. (*a*) Samples of crushed stone for mechanical analysis shall conform to the following weight requirements:

NOMINAL MAXIMUM SIZE OF PARTICLE, IN.	MINIMUM WEIGHT OF SAMPLE, G.
$\frac{3}{8}$	1 000
$\frac{1}{2}$	2 500
$\frac{3}{4}$	5 000
1	10 000
$1\frac{1}{2}$	15 000
2	20 000
$2\frac{1}{2}$	25 000
3	30 000
$3\frac{1}{2}$	35 000

It was announced that the committee had completed the preparation of Specifications for Asphalt Plank and a revision of the Tentative Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131 - 37 T), which, after approval by letter ballot of the committee, would be submitted for publication as tentative to the Society through Committee E-10 on Standards subsequent to the annual meeting.

The report of Committee D-8 on Bituminous Waterproofing and Roofing Materials was presented by the chairman, J. M. Weiss. The proposed Tentative Specifications for Asphalt Mastic for Use in Waterproofing (Asphalt Cement, Mineral Filler, Mineral Aggregates) were accepted for publication as tentative. The proposed revisions of the Tentative Specifications for Coal-Tar Pitch for Roofing, Damp-proofing and Waterproofing (D 450 - 37 T) were accepted, the specifications as revised being continued as tentative.

The editorial change in Section 2 of the Tentative Methods of Test for Sieve Analysis of Granular Mineral Surfacing for Asphalt Roofing and Shingles (D 451 - 37 T), and of Test for Sieve Analysis of Non-Granular Mineral Surfacing for Asphalt Roofing and Shingles (D 452 - 37 T) was accepted. An additional editorial change in these two methods, presented on the floor at the annual meeting, providing for the omission of the note appearing in connection with Table I, was also accepted.

The recommendation that the following five standards be reverted to tentative was accepted, the change in status to become effective in 1939: Standard Specifications for Asphalt Mastic for Use in Waterproofing (D 169 - 25), for Bituminous Grout for Use in Waterproofing Above Ground Level (D 170 - 25), for Bituminous Grout for Use in Waterproofing Below Ground Level (D 171 - 25), for Acid-Resisting Asphalt Mastic (D 223 - 30), and Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (D 147 - 27).

The recommendation that the Standard Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (D 173 - 27), for Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (D 226 - 27), and Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing (D 146 - 37) be reverted to tentative, as revised, was accepted, with the following modification in the revision proposed in Section 8 in Specifications D 226 - 27:

Section 8.—Change the requirement in Paragraph (*c*) of this section from the form as preprinted to read as follows by the addition of the italicized word and the omission of the figures in brackets:

	15-LB. TYPE	30-LB. TYPE
(c) *Minimum* weight of saturated felt per 100 sq. ft. (exclusive of wrapping and packing material), lb.	14 [±1]	29 [±1½]

The withdrawal of the Standard Specifications for Burlap Saturated with Bituminous Substances for Use in Waterproofing (D 174 – 25) was approved.

It was announced that Committee D-8, in cooperation with Committee D-4 on Road and Paving Materials, would submit to the Society through Committee E-10 on Standards, subsequent to the annual meeting, a new tentative volume correction table for tars based on the coefficients of expansion appearing in the report of Committee D-8. It was also announced that the committee would submit to Committee E-10 revisions in the Tentative Method of Testing Films Deposited from Bituminous Emulsions (D 466 – 37 T) subsequent to the annual meeting.

A paper entitled "Effect of Sulfur upon Some of the Properties of Asphalts," by Isaac Bencowitz and E. S. Boe, was presented by Mr. Bencowitz and discussed.

The report of Committee D-18 on Soils for Engineering Purposes was presented by the secretary, W. R. Nelson. The proposed revisions of the Tentative Methods of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (D 421 – 35 T), of Test for Plastic Limit and Plasticity Index of Soils (D 424 – 35 T), of Test for Centrifuge Moisture Equivalent of Soils (D 425 – 35 T), of Test for Field Moisture Equivalent of Soils (D 426 – 35 T), and of Test for Shrinkage Factors of Soil (D 427 – 35 T) were accepted, the methods as revised being continued as tentative. The proposed revisions of the Tentative Method of Mechanical Analysis of Soils (D 422 – 35 T) were accepted, with the exception of the change in Section 6 (*a*), which was withdrawn by the committee. The proposed revision of the Tentative Method of Test for Liquid Limit of Soils (D 423 – 35 T) was accepted, with the exception of the proposed change in Section 1, which was withdrawn by the committee.

In presenting the report the chairman called upon the individuals indicated to present, from manuscript, the following papers prepared by members of the committee:

"Important Considerations in Soil Mechanics,"[1] by C. A. Hogentogler and Harold Allen, presented by Mr. Allen and discussed.

"A Study of Deflocculating Agents Used in the Particle Size Determination of Soils," by Edward E. Bauer, presented by T. J. Dolan.

The following papers were then presented by the respective authors and discussed:

"The Grading-Density Relations of Granular Materials," by Donald M. Burmister.

"A Machine for Testing Highway Subgrade Soils," by E. O. Rhodes, presented from manuscript.

The meeting then adjourned till 2 p. m.

THIRTEENTH SESSION

Thursday, June 30, 2 p. m.

Ceramic and Masonry Materials, Lime, Gypsum

Mr. P. H. Bates and Past-President T. R. Lawson, co-chairmen.

The report of Committee C-15 on Manufactured Masonry Units was presented by the chairman, D. E. Parsons.

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[1] Published in ASTM BULLETIN, No. 94, October 1938, p. 15.

The new Specifications for Concrete Masonry Units for Use in Construction of Catch Basins and Manholes and the Methods of Sampling and Testing Concrete Masonry Units were accepted for publication as tentative. The revised Specifications for Structural Clay Load-Bearing Wall Tile were accepted for publication as a tentative revision of the present Standard Specifications C 34 – 36. The revised Specifications for Sand-Lime Building Brick were accepted for publication as tentative to replace immediately the Standard Specifications C 73 – 37, which were withdrawn.

The proposed revisions of the Tentative Specifications for Paving Brick (C 7 – 37 T) and for Concrete Units for Non-Load-Bearing Masonry (C 129 – 37 T) were accepted, the specifications as revised being continued as tentative.

The proposed revisions of the Standard Specifications for Structural Clay Non-Load-Bearing Tile (C 56 – 36) and for Structural Clay Floor Tile (C 57 – 36) were accepted for publication as tentative.

The withdrawal of the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30) was approved.

In connection with the presentation of the report Mr. Parsons called upon W. J. Krefeld to present his papers on

> "Effect of Shape of Specimen on the Apparent Compressive Strength of Brick Masonry."

A paper entitled "Freezing-and-Thawing Tests for Building Brick," by J. W. McBurney and A. R. Eberle, was presented by Mr. McBurney.

The report of Sectional Committee A42 on Specifications for Plastering was presented from manuscript by the secretary, J. W. McBurney.

The report of Committee C-8 on Refractories was presented by the chairman, J. D. Sullivan. The new Methods of Test for Size, Warpage, and Bulk Specific Gravity of Refractory Brick, and Test for True Specific Gravity of Burned Refractory Materials, with certain editorial changes presented on the floor at the annual meeting, were accepted for publication as tentative.

The proposed revisions of the Standard Specifications for Fireclay Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 – 36), for Fireclay Brick for Stationary Boiler Service (C 64 – 36), for Fireclay Brick for Marine Boiler Service (C 65 – 28), for Refractories for the Construction of Incinerators (C 106 – 36), and Definitions for Fireclay Refractories (C 27 – 37) were accepted for publication as tentative.

The editorial changes in the preface and Sections 9 and 31 of the Tentative Methods of Chemical Analysis of Refractory Materials (C 18 – 37 T) were accepted, the methods as revised being continued as tentative.

The report of Committee C-18 on Natural Building Stones and Slate was presented from manuscript by the vice-chairman, T. I. Coe.

The report of Committee C-11 on Gypsum was presented by the Secretary-Treasurer. The proposed revisions of the Standard Specifications for Keene's Cement (C 61 – 30), for Gypsum Plasters (C 28 – 30), and Methods of Testing Gypsum and Gypsum Products (C 26 – 33) were accepted for publication as tentative. The withdrawal of the Standard Specifications for Calcined Gypsum (C 23 – 30) was approved.

The report of Committee C-7 on Lime was presented by the chairman, James R. Withrow. The proposed Specifications for Quicklime for Causticizing Leached Liquors in the Soda-Pulp Process for the Manufacture of Paper, for Quicklime for Use in the Manufacture of Paper Pulp Where the Precipitated Carbonate Is Employed as a Pigment or Filler, and Method for Determination of Available Lime in High-Calcium Quicklime and Hydrated Lime by the Rapid Sugar Test were accepted for publication as information.

The proposed revision of the Tentative Methods of Physical Test for Limestone, Quicklime and Hydrated Lime (C 110 – 34 T), providing for the deletion of the soundness test in Sections 4 and 5, was discussed and, on motion, was accepted.

A motion for acceptance of the report, after discussion, failed to receive the necessary two-thirds vote of those voting at the session, the results of the vote being 13 affirmative and 7 negative.

Attention was then called to the fact that Committee C-7, at its meeting held on Thursday, June 30, had approved the following addition to its report, to be inserted in connection with the revision in the Tentative Methods of Physical Test for Limestone, Quicklime and Hydrated Lime (C 110 – 34 T):

> During the coming year the committee plans to continue its investigation of methods for determining the soundness of limes, the results of which will be submitted as a progress report at the next annual meeting of the Society.

On motion, it was voted to amend the report by adding the above paragraph to the report. The report, as thus amended, was then accepted for publication.

The report of Committee C-14 on Glass and Glass Products was presented from manuscript by the vice-chairman, F. C. Flint.

A progress report of Committee C-12 on Mortars for Unit Masonry[1] was presented from manuscript by the chairman, J. W. McBurney.

The meeting then adjourned till 8 p. m.

FOURTEENTH SESSION

Thursday, June 30, 8 p. m.

Iron

President A. E. White and Past-President H. F. Moore, co-chairmen.

The report of Committee A-2 on Wrought Iron was presented by the chairman, J. B. Young. The revision proposed for immediate adoption in the Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 33) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote. The proposed revision of the Tentative Specifications for Rolled Wrought-Iron Shapes and Bars (A 207 – 37 T) was accepted, the specifications as revised being continued as tentative.

The report of Committee A-3 on Cast Iron was presented by J. T. MacKenzie. The proposed revision of the Standard Specifications for Gray-Iron Castings for Valves, Flanges, and Pipe Fittings (A 126 – 30) was accepted for publication as tentative. The Tentative Specifications for Cast-Iron Culvert Pipe (A 142 – 35 T), as revised, were approved for reference to letter ballot of the Society for adoption as standard.

A progress report of Committee A-7 on Malleable-Iron Castings was presented from manuscript by Hyman Bornstein.

A paper entitled "The Properties and Uses of Chilled Iron," by S. C. Massari, was presented by the author and discussed.

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[1] Published in ASTM BULLETIN, No. 93, August 1938, p. 31.

An informal report of progress on the work of Sectional Committee A21 on Specifications for Cast-Iron Pipe and Special Castings was presented by J. T. MacKenzie.

The following papers were presented and discussed:

"Effect of Size and Type of Specimen on the Torsional Properties of Cast Iron," by Jasper O. Draffin and W. L. Collins, presented by Mr. Collins.

"Note on the Hardness Measurements of Very Hard Steels and White Cast Irons," by J. S. Vanick and J. T. Eash, presented by Mr. Vanick.

The meeting then adjourned till the following morning.

FIFTEENTH SESSION

Thursday, June 30, 8 p. m.

Petroleum Products, Fuels, Electrical Insulating Materials

Mr. H. C. Mougey in the chair.

The report of Sectional Committee M20 on Classification of Coals was presented by the chairman, A. C. Fieldner. The new Definitions of Varieties of Bituminous and Subbituminous Coals were accepted for publication as tentative. The revision proposed for immediate adoption in the Standard Specifications for Classification of Coals by Rank (D 388 – 37) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote. The Tentative Method for Designating the Size of Coal from Its Screen Analysis (D 431 – 36 T) was approved for reference to letter ballot of the Society for adoption as standard.

The report of Committee D-5 on Coal and Coke was presented by the chairman, A. C. Fieldner. The new Method of Sampling Coals Classed According to Ash Content, with certain editorial changes presented on the floor at the annual meeting, was accepted for publication as tentative. The proposed revision of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 37) was accepted for publication as tentative. The Tentative Method of Test for Screen Analysis of Coal (D 410 – 35 T), as revised, was approved for reference to letter ballot of the Society for adoption as standard.

The report of Committee D-3 on Gaseous Fuels was presented by the chairman, A. C. Fieldner.

The report of Committee D-9 on Electrical Insulating Materials was presented by the chairman, T. Smith Taylor. The new Methods of Testing Solid Electrical Insulating Materials for Arc Resistance, and of Acetone Extraction of Phenolic Molded or Laminated Products were accepted for publication as tentative.

The proposed revisions of the Tentative Methods of Testing Varnishes Used for Electrical Insulation (D 115 – 36 T), of Testing Sheet, Tape, and Molded Insulating Materials for Dielectric Strength (D 149 – 36 T), of Testing Untreated Paper Used in Electrical Insulation (D 202 – 36 T), of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 37 T), of Testing Laminated Tubes Used in Electrical Insulation (D 348 – 35 T), and of Testing Flexible Varnished Tubing Used for Electrical Insulation (D 350 – 37 T) were accepted, the methods as revised being continued as tentative.

The proposed revision of the Tentative Methods of Testing Varnished Cloths and Varnished Cloth Tapes Used in Electrical Insulation (D 295 – 37 T) was accepted with the exception of the procedure for humidity treatment which was withdrawn by the committee.

The proposed revisions of the Standard

Methods of Testing Molded Materials Used for Electrical Insulation (D 48 - 37), and of Testing Pasted Mica Used in Electrical Insulation (D 352 - 36) were accepted for publication as tentative.

The Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T), as revised, of Test for Insulation Resistance of Electrical Insulating Materials (D 257 - 37 T), as revised, of Test for Grading Natural Mica (D 351 - 36 T), and of Testing Molding Powders Used in Manufacturing Molded Electrical Insulators (D 392 - 35 T) were approved for reference to letter ballot of the Society for adoption as standard.

It was announced that revisions in the Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 - 37 T) and of Testing Pin-Type, Lime Glass Insulators (D 468 - 37 T), after approval by letter ballot of the committee, would be submitted to the Society through Committee E-10 on Standards subsequent to the annual meeting. It was also announced that the committee recommended the withdrawal of the Tentative Method of Test for Saponification Number of Electrical Insulating Oils (Modified Baader Method) (D 438 - 36 T), which was being replaced by a new tentative method recommended jointly by Committee D-9 and Committee D-2 on Petroleum Products and Lubricants.

The report of Committee D-2 on Petroleum Products and Lubricants was presented by the secretary, R. P. Anderson. The new Method of Test for Acid Heat of Gasoline, and Specifications for Stoddard Solvent were accepted for publication as tentative. A new Method of Test for Unsulfonated Residue of Plant Spray Oils was accepted for publication as tentative, with the following modification in Section 3 (*d*) presented on the floor of the annual meeting subject to favorable letter ballot of Committee D-2:[1]

Section 3 (d).—Change from the form as preprinted to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*d*) *Test Bottles.*—The test bottles shall be made of good quality glass and the preferred form shall conform to the dimensions given in Fig. 1. The capacity to base of neck shall be 45 to 50 ml. [As an alternative, the standard "6-in., 9-g., 50 per cent × ½ cream bottle" may be used provided equal accuracy is maintained.] The graduated portion of the bottle shall contain 5 ± 0.025 ml. (at a temperature of 77 F. (25 C.)) and shall be graduated in 100 divisions, the first and each succeeding tenth line to extend at least three-fourths of the distance around the neck and to be numbered from the bottom 5, 10, etc. Within the range from 0 to 50, the maximum error in volume shall not be greater than 0.025 ml. The graduation marks shall be clear and fine, not more than 0.3 mm. in width. *As an alternative, the standard "6-in., 9-g., 50 per cent × ½ cream bottle" may be used. In this bottle the maximum error in volume of the graduated portion shall not be greater than 0.05 ml. to conform to the established standard.* The bottom of the bottles shall have a ground area of at least 2 sq. cm. for numbering.

The proposed revisions of the Tentative Method of Test for Vapor Pressure of Petroleum Products (Reid Method) (D 323 - 37 T) were accepted, with the following additional changes presented on the floor at the annual meeting subject to favorable letter ballot of Committee D-2:[2]

Section 1.—Change the second sentence of the note following this section to read as follows by the addition of the italicized figure:

> Sections 10 to 15, inclusive, shall be followed for products in the first group, and Sections 10, *13*, 21, and 22 for products in the second group.

Section 2 (e).—Add a new note following this paragraph to read as follows:

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[1] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 42 voted affirmatively and 0 negatively.

[2] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 47 voted affirmatively and 0 negatively.

NOTE.—In determining capacities for the apparatus shown in Fig. 1 (*b*), the capacity of the gasoline chamber shall be considered as that below the gate-valve closure. The volume above the gate-valve closure including the portion of the coupling permanently attached to the gasoline chamber shall be considered as a part of the air-chamber capacity.

Section 6.—Add a new note following this section to read as follows:

NOTE.—As an alternate, the oil-tube thermometer having a range of 94 to 108 F. as prescribed in the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88) of the American Society for Testing Materials may be used.

Sampling Procedures for Products Having Vapor Pressures Over 26 lb.—Change the second paragraph of the explanatory material under this heading to read as follows by the addition of the italicized figure:

The complete method for products under this title comprises Sections 1 to 3, 5 to 7, 10, 21, 22, *13*, and 16 to 20, in the order listed.

The proposed revisions of the Tentative Methods of Test for Knock Characteristics of Motor Fuels (D 357 – 37 T) were accepted, with the following additional changes presented on the floor at the annual meeting subject to favorable letter ballot of Committee D-2:[1]

Section 3 (t).—Change the second sentence from the form as preprinted to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

[This pipe] *It* shall be made [from 1¼-in. pipe] *of pipe not less than 1¼ in. in inside diameter* having a maximum of two ells [with] *and* a total length not to exceed 20 ft.

Section 6 (f).—In Note 4 following this section change the compression ratio from "7:1 ± 0.2" to read "7.1 ± 0.2 to 1."

Section 8.—Change the formula for calculating compression ratio from the form as preprinted: namely,

Compression ratio $= 5.30 + (29.92 - B)\ 0.16$
where:
B = the barometric pressure in inches of mercury corrected to a temperature of 28.5 F. (— 1.95 C.)

to read as follows:

$\text{C.R.} = 5.30 + (29.92 - B)\ 0.16$
where:
C.R. = the compression ratio, and
B = the barometric pressure in inches of mercury measured by a brass scale, corrected to a temperature of 28.5 F. (– 1.95 C.)[a]

[a] $B = B' - 0.00009\ B'\ (t' - 28.5)$
B' = the observed barometric pressure, and
t' = the observed temperature of the barometer in deg. Fahr.

Section 10 (b).—Change the last sentence from the form as preprinted, namely:

The standard knockmeter reading (55 to 60) should be obtained at 7:1 ± 0.2 compression ratio corrected for barometric pressure.

to read as follows:

The standard knockmeter reading (55 to 60) should be obtained at 7.1 ± 0.2 to 1 compression ratio corrected for barometric pressure in accordance with the following formula:
$\text{C.R.} = 7.1 + (29.92 - B)\ 0.21$
where:
C.R. = the compression ratio, and
B = the barometric pressure in inches of mercury measured by a brass scale, corrected to a temperature of 28.5 F. (– 1.95 C.)

The proposed revision of the Tentative Methods of Test for Kinematic Viscosity (D 445 – 37 T) was accepted, the methods as revised being continued as tentative.

The revision proposed for immediate adoption in the Standard Methods of Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water) (D 158 – 28) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote, with the following additional changes presented on the floor at the annual meeting subject to favorable letter ballot of Committee D-2:[1]

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[1] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 45 voted affirmatively and 1 negatively.

Section 2 (h).—Change from the form as preprinted: namely,

> (*h*) *Graduate for Sample.*—A graduate or pipette graduated to deliver 200 ± 1.0 ml., may be used for measuring the sample to be tested.

to read as follows:

> (*h*) *Graduate for Sample.*—A 200 ± 0.2-ml. pipette or a cylinder graduated to deliver 200 or 250 ± 1.4 ml., may be used for measuring the sample to be tested.

Section 2 (j).—Change the second and third sentences from the form as preprinted: namely,

> The cylinder shall be graduated to contain 25 ml. and the graduated portion shall be not less than 3¼ in. (8.25 cm.) nor more than 3¾ in. (9.52 cm.) in length. It shall be graduated in half milliliters and each tenth mark (indicating multiples of 5 ml.) shall be distinguished by a longer line.

to read as follows:

> The cylinder shall be graduated for 25 ml. and the graduated portion shall be not less than 3 in. (7.6 cm.) nor more than 3¾ in. (9.52 cm.) in length. It shall be graduated in half milliliters. Each 1-ml. line shall be longer than the 0.5-ml. lines, and each 5-ml. line shall encircle the cylinder.

The Tentative Method of Test for Color of Refined Petroleum Oil by Means of Saybolt Chromometer (D 156 – 34 T) was approved for reference to letter ballot of the Society for adoption as standard.

The tentative revision of the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (D 88 – 36) was approved for reference to letter ballot of the Society for adoption as standard, with the following additional change presented on the floor at the annual meeting subject to favorable letter ballot of Committee D-2:[2]

Section 4 (d).—In place of the new second sentence, proposed in the original revision, which reads as follows:

> In case the flash point is less than 50 F. (10 C.) above the temperature of test, the oil shall be heated to room temperature only.

substitute the following:

> In no case, however, shall the oil be preheated to a temperature above 50 F. below the flash point.

The following immediate revision of the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 – 35), presented on the floor at the annual meeting, was approved for reference to letter ballot of the Society for adoption as standard, subject to favorable letter ballot of Committee D-2:[3]

Section 9.—Add the following new paragraph at the end of this section:

> The sum of the volume collected in the cylinder at any specified temperature and the distillation loss may be recorded as the percentage evaporated at the temperature in question.

A new Tentative Method of Test for Ash Content of Petroleum Oils, presented on the floor at the annual meeting, was accepted for publication as tentative subject to favorable letter ballot of Committee D-2.[4]

A new Tentative Method of Test for Saponification Number, presented on the floor at the annual meeting jointly with Committee D-9 on Electrical Insulating Materials, to replace immediately the present Standard Method of Test for Saponification Number (D 94 – 36) and the Tentative Method of Test for Saponification Number of Electrical Insulating Oils (Modified Baader Method) (D 438 – 36 T), was accepted for publication as tentative subject to favorable letter ballot of Committee D-2.[1]

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[1] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 46 voted affirmatively and 2 negatively.

[2] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 51 voted affirmatively and 1 negatively.

[3] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 49 voted affirmatively and 0 negatively.

[4] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 50 voted affirmatively and 1 negatively.

A revision of the Tentative Method of Test for Greases and Petrolatum (D 217-33 T), presented on the floor at the annual meeting in the form of a completely rewritten method entitled, "Tentative Method of Test for Consistency of Lubricating Greases and Petrolatum," was accepted subject to favorable letter ballot of Committee D-2.[2]

The following editorial revision of the Tentative Method of Test for Expressible Oil and Moisture in Paraffin Waxes (D 308 - 29 T), presented on the floor at the annual meeting, was accepted subject to favorable letter ballot of Committee D-2:[3]

Section 7.—Change this section from its present form: namely,

> 7. *Cloth.*—The cloth shall be a white or colored "silesia" or "duretta" or similar tightly-woven cloth free from nap. The cloth shall be accurately cut in disks 3.50 in. in diameter.

to read as follows:

> 7. *Cloth.*—The cloth shall be a clean, white, tightly-woven cotton fabric conforming to the following requirements:

Threads per inch in warp	100 to 110
Threads per inch in filling	60 to 65
Weave	twill
Weight per square yard, oz	4.7 to 4.9
Sizing material	none

> These specifications can be met in a "silesia" or "duretta" or similar fabric. The cloth shall be accurately cut in disks 3.50 in. in diameter.

The following tentative revision of the Standard Method of Test for Cloud and Pour Points (D 97 - 34), presented on the floor at the annual meeting, was accepted subject to favorable letter ballot of Committee D-2:[4]

> 13. *Reproducibility of Results.*—Individual results of the pour test on the same oil in any one laboratory may vary by 5 F. and in different laboratories by 10 F., although the average of three or more results in different laboratories should show a difference between averages no greater than 5 F. For oils tested by the special procedure described in Section 12, reproducibility of this order cannot be expected, as these oils show anomalous pour points depending on their previous thermal history.[a]
>
> [a] It is a recognized property of these oils that the temperature to which they have been subjected before testing influences their pour points. Although the lower pour points as determined by the special procedure will show approximately the reproducibility given above, yet the upper pour points will show greater variations depending on the previous thermal history of the oils. Further information on this subject is contained in *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, pp. 468 to 470 (1931), and Vol. 32, Part I, pp. 402 to 405 (1932).

The following tentative revision of the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 - 37), presented on the floor at the annual meeting, was accepted subject to favorable letter ballot of Committee D-2:[5]

Section 6 (b) and (c).—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets.

> (*b*) *Crude Petroleum or a Product Thereof* [A product] with *an* initial boiling point below 250 F. (121.1 C.) and an A.P.I. gravity below 70 *deg.* shall be cooled in the original closed container to a temperature of 65 F. (18.3 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum or a product thereof* [A product] having an A.P.I. gravity of 70 *deg.* or greater shall be cooled in the original closed container to a temperature of 35 F. (1.7 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum having an initial boiling point below 250 F. (121.1 C.) which has too high a pour point or is too viscous at 65 F. (18.3 C.) to permit an accurate hydrometer reading at 65 F. (18.3 C.) or below should be heated to the minimum temperature which will give sufficient fluidity to permit an accurate hydrometer reading.*

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[1] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 46 voted affirmatively and 0 negatively.

[2] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 48 voted affirmatively and 0 negatively.

[3] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 40 voted affirmatively and 0 negatively.

[4] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 49 voted affirmatively and 0 negatively.

[5] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 50 voted affirmatively and 0 negatively.

(*c*) The thermometer, hydrometer, and hydrometer cylinder shall be at approximately the same temperature as the *sample* [product] to be tested. Precaution shall be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing nonvolatile and nonviscous *samples* [oils] by choosing a temperature of test only slightly different from the room temperature. When volatile [products] *samples (those having initial boiling points below 250 F. (121.1 C.) and also those having A.P.I. gravities greater than 70 deg.)* are cooled, or viscous [products] *samples are* heated, the test cylinder shall be placed in a bath maintained at the *necessary* [a constant desired] temperature during the time of test. *In determining the gravity of any crude petroleum or product, the temperature of the surrounding medium should not differ from the temperature of the sample by more than 5 F. (2.8 C.).*

A Proposed Method of Test for Ignition Quality of Diesel Fuels, presented on the floor at the annual meeting, was accepted for publication as information in an appendix to the report subject to favorable letter ballot of Committee D-2.[1]

The following revisions in the Diesel-Fuel-Oil Classification, presented on the floor at the annual meeting, were accepted subject to favorable letter ballot of Committee D-2,[2] the revised classification to be published as information in an appendix to the report:

Table I.—Change the minimum viscosity limits for oils Nos. 1-D and 3-D from "35 sec." to read "33 sec."

Change footnotes *a* and *c* from their present form: namely,

[a] Minimum flash point, as stated or as required by local fire regulations, Fire Underwriters or state laws.

[c] Lower pour points may be specified whenever required by local temperature conditions to facilitate storage and use, although the minimum viscosity specified for Oils Nos. 1-D and 3-D must be waived whenever it is necessary to require a pour point of less than 10 F.

to read as follows:

[a] Minimum flash point, as stated or as required by local fire regulations, fire underwriters, or state laws.

[c] Lower pour points may be specified whenever required by local temperature conditions to facilitate storage and use.

Delete from the classification, oils Nos. 5-D and 6-D and insert the following as a footnote after oil No. 4-D:

Oils more viscous than No. 4-D are available and may be purchased by special negotiations between the purchaser and the seller.

Table II.—Change from its present form: namely,

TABLE II.—IGNITION QUALITY.[a]

	Oil Grades		
	No. 1-D	No. 3-D	No. 4-D
Cetane number by the delay method, min.......	45	35	30
Diesel index number, min.	45	30	20
Viscosity-gravity number, max..................	0.86	0.89	0.91
Boiling-point - gravity number, max..........	188	195	200

[a] The values in Table II are equivalent within the limits of error of the test methods used. As the correlations between indexes and between any index and engine operation in the field are not completely established as yet, these values should be used in an approximate way only.

to read as follows:

TABLE II.—IGNITION QUALITY.

	Grade No. 1-D	Grade No. 3-D	Grade No. 4-D
Cetane number, min............	45	35	30
Diesel index number,[a] min.......	45	32	25

[a] In many cases the Diesel Index may prove more convenient than cetane number and equally satisfactory. It is reliable for hydrocarbon fuels which have 50 per cent boiling points between 490 and 575 F. It cannot apply in the case of fuel containing an ignition promotor ("doped" fuel).

Under the Section on Methods of Testing replace the description of the ash test in Paragraph (*e*) by the following reference:

(*e*) *Ash.*—Tentative Method of Test for Ash Content of Petroleum Oils (A.S.T.M. Designation: D 482) of the American Society for Testing Materials.

In Paragraph (*i*) on ignition quality replace the description of the test for cetane number by the following reference:

CETANE NUMBER.—Proposed Method of Test for Ignition Quality of Diesel Fuels.

The report of Sectional Committee Z-11 on Petroleum Products and Lubricants was presented from manuscript by the secretary, R. E. Hess.

The following papers were then presented and discussed:

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[1] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 42 voted affirmatively and 2 negatively.

[2] This recommendation was submitted to letter ballot of Committee D-2, which consists of 78 voting members; 52 members returned their ballots, of whom 40 voted affirmatively and 1 negatively.

"Some Applications of an Accelerated Test for Determining the Chemical Stability of Lubricating Greases," by F. L. Wright and H. A. Mills, presented by Mr. Wright.

"Studies in the Oxidation of Mineral Transformer Oil," by F. M. Clark, presented by the author.

The meeting then adjourned till the following morning.

SIXTEENTH SESSION

Friday, July 1, 9.30 a. m.

Non-Ferrous Metals, Spectrography

Messrs. T. S. Fuller and T. A. Wright, co-chairmen.

A progress report of Committee E-2 on Spectrographic Analysis was presented from manuscript by the chairman, H. V. Churchill.

A paper entitled "An Arc Source for Quantitative Spectral Analysis," by C. J. Neuhaus, was presented by the author and discussed.

The report of Committee E-3 on Chemical Analysis of Metals was presented from manuscript by the chairman, G. E. F. Lundell. It was announced that the committee had completed an extensive revision of the Tentative Methods of Chemical Analysis of Ferro-Alloys (A 104 – 36 T) which, after approval by letter ballot of the committee, would be submitted for publication as tentative to the Society through Committee E-10 on Standards subsequent to the annual meeting.

The report of Committee B-1 on Copper and Copper-Alloy Wires for Electrical Conductors was presented by the Assistant Secretary. The proposed revision of the Tentative Specifications for Hard-Drawn Copper Alloy Wires for Electrical Conductors (B 105 – 37 T) was accepted, the specifications as revised being continued as tentative.

The revisions proposed for immediate adoption in the Standard Specifications for Hard-Drawn Copper Wire (B 1 – 27), for Medium-Hard-Drawn Copper Wire (B 2 – 27), for Soft or Annealed Copper Wire (B 3 – 27), for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 – 21), for Soft Rectangular Copper Wire (B 48 – 27), for Bronze Trolley Wire (B 9 – 37), and for Copper Trolley Wire (B 47 – 37) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

It was announced that the committee had decided to recommend the revision in the Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (B 8 – 36) for publication as tentative rather than for immediate adoption as originally proposed in the report as preprinted. The revised Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft, were accordingly accepted for publication as a tentative revision of the Standard Specifications B 8 – 36, with the additional changes given below presented on the floor at the annual meeting, subject to favorable letter ballot of Committee B-1.[1] Specifications B 8 – 36 will be continued as standard but the withdrawal of the Standard Specifications for Hard-Drawn Copper Transmission Cable (B 87 – 32 T) was approved.

Section 7 (b).—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> Two per cent shall be taken as the standard increment of increase of resistance and weight of concentric-lay cable except [as modified by the provision in Note 7] *that 1 per cent shall be taken as the standard increment for cable composed of three wires.*

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[1] This recommendation was submitted to letter ballot of Committee B-1, which consists of 30 members; 28 members returned their ballots, of whom 21 voted affirmatively and 2 negatively.

Section 9 (a).—Change this section from the form as preprinted: namely,

> 9. *(a)* Package sizes for cable shall be agreed upon in the placing of individual orders (Notes 5 and 6). Lengths as shipped shall be not less than 90 per cent nor more than 110 per cent of the lengths specified in the order except as may be agreed to by the purchaser.

to read as follows:

> 9. *(a)* Package sizes for cable shall be agreed upon in the placing of individual orders (Notes 5 and 6). Unless otherwise agreed upon by the purchaser and the manufacturer, 90 per cent of the lengths as shipped on any one item shall be not less than 90 per cent nor more than 110 per cent of the length specified in the order. The remainder of the item may be shipped in random lengths of not less than 50 per cent of the specified length.

Table III.—Delete footnote *c* which includes a table of assumed lay and calculated increments in weight; also footnote *d* and the last column of the table which covers the reel designations.

Note 7.—Delete this note which reads as follows:

> NOTE 7.—One per cent shall be taken as the standard increment of increase of resistance and weight of 3-wire cable.

The report of Committee B-2 on Non-Ferrous Metals and Alloys was presented from manuscript by the secretary, E. E. Thum. It was announced that the committee had completed the preparation of new Specifications for Electrolytic Cathode Copper and revisions in the Standard Specifications for Phosphor Tin (B 51 – 27), for Phosphor Copper (B 52 – 27), for Silicon Copper (B 53 – 27) and for Brazing Solder (B 64 – 28) which, after approval by letter ballot of the committee, would be submitted for publication as tentative to the Society through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "Compressive, Impact, and Other Mechanical Properties of Nickel and Some of Its High-Strength, Corrosion-Resisting Alloys," by Charles F. Catlin and W. A. Mudge, was presented by Mr. Mudge and discussed.

The report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys was presented by the chairman, T. S. Fuller. In presenting the report Mr. Fuller called upon W. H. Finkeldey to describe the activities of Subcommittee VI on Atmospheric Corrosion of Non-Ferrous Metals and Alloys.

The report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, was presented by the chairman, C. H. Greenall. The report was accepted with the omission of item 4 under the activities of Subcommittee II which appeared on page 5 of the report as preprinted and the inclusion of the following paragraph:

> In order to simplify the preparation of specifications for the many copper-base casting alloys, some grouping of similar alloys seemed desirable. As a possible A.S.T.M. recommended practice, the committee is considering the rather complete classification and nomenclature appearing in the 1938 Casting Manual—Non-Ferrous Metals, published by *Metal Industry*, New York City. The adoption of a classification of this nature would not prevent the use of names for individual alloys such as have acquired commercial value through use but would facilitate the writing of specifications covering groups of alloys of somewhat similar composition.

The proposed revisions of the Tentative Specifications for Wrought Phosphor Bronze Bearings and Expansion Plates for Bridges and Structures (B 100 – 35 T), and for Bronze Castings for Turntables and Movable Bridges (B 22 – 36 T) were accepted, the specifications as revised being continued as tentative. The proposed revisions in the Tentative Specifications for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (B 111 – 37 T) were accepted, with the exception of the proposed change in Section 4 which was withdrawn by the committee. It was announced that the committee had completed further revisions in Specifications B 111 which, after approval by letter ballot of the committee, would be submitted for publication as tentative to the

Society through Committee E-10 on Standards subsequent to the annual meeting.

The revisions proposed for immediate adoption in the Standard Specifications for Aluminum-Bronze Castings (B 59 - 36) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed revision of the Standard Specifications for Sheet High Brass (B 36 - 33) in the form of new Tentative Specifications for Brass Sheet and Strip, was accepted for publication to replace immediately the existing standard.

The Tentative Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 - 36 T), and for Car and Tender Journal Bearings, Lined (B 67 - 36 T) were approved for reference to letter ballot of the Society for adoption as standard.

The withdrawal of the Standard Specifications for Yellow Brass Sand Castings for General Purposes (B 65 - 28) was approved.

It was announced that the committee had decided to withdraw from the report as preprinted the recommendation for discontinuing the Tentative Specifications for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent (B 74 - 32 T), which will accordingly be continued as tentative.

The report of Committee B-6 on Die-Cast Metals and Alloys was presented by the chairman J. R. Townsend. The proposed revisions of the Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 - 34 T) were accepted with the exception of the footnote recommended for inclusion in Section 9 and the note proposed for inclusion in the revised Section 11, which were withdrawn by the committee.

The proposed revisions in the Tentative Specifications for Aluminum-Base Alloy Die Castings (B 85 - 37 T), for Magnesium-Base Alloy Die Castings (B 94 - 37 T), and for Lead- and Tin-Base Alloy Die Castings (B 102 - 35 T), which appeared in the report as preprinted, were withdrawn by the committee for further study.

The report of Committee B-7 on Light Metals and Alloys, Cast and Wrought, was presented by the chairman, Sam Tour. The new Method of Test for Dielectric Strength of Anodized Aluminum was accepted for publication as tentative. The proposed Specifications for Aluminum-Base Alloys in Ingot Form for Die Castings and the proposed revision of the Standard Specifications for Aluminum Ingots for Remelting (B 24 - 29), which appeared in the report as preprinted, were withdrawn by the committee.

The proposed revisions of the Tentative Specifications for Magnesium-Base Alloy Sand Castings (B 80 - 36 T), for Magnesium-Base Alloy Sheet (B 90 - 36 T), for Magnesium-Base Alloy Forgings (B 91 - 36 T), for Magnesium-Base Alloy Bars, Rods, and Shapes (B 107 - 36 T), for Magnesium-Base Alloy Ingot for Remelting (B 93 - 36 T), for Aluminum-Base Alloys in Ingot Form for Permanent Mold Castings (B 112 - 37 T), for Aluminum-Manganese Alloy Sheet and Plate (B 79 - 36 T), for Aluminum Sheet and Plate (B 25 - 36 T), and for Aluminum-Base Alloy Permanent Mold Castings (B 108 - 37 T) were accepted, the specifications as revised being continued as tentative.

The report of the Joint Committee on Exposure Tests of Plating on the Non-Ferrous Metals was presented by the chairman, W. Blum.

The meeting then adjourned.

SEVENTEENTH SESSION

Friday, July 1, 9.30 a. m.

Soap, Textiles, Paint, Plastics, Rubber

Messrs. M. F. Skinker and R. D. Bonney, co-chairmen.

The report of Committee D-12 on Soaps and Detergents was presented by the chairman, H. P. Trevithick. The new Specifications for White Floating Toilet Soap, for Chip Soap, for Powdered Laundry Soap, for Ordinary Laundry Bar Soap, and Methods of Test for Particle Size of Soaps and Other Detergents, of Chemical Analysis of Sulfonated (Sulfated) Oils, and of Chemical Analysis of Special Detergents were accepted for publication as tentative. The new Methods for Determination of Combined Sodium and Potassium Oxides in Soaps (D 460 – 38 T) were accepted for publication as tentative to be included in the existing general methods of chemical analysis of soaps.

The recommendation for adoption as standard of the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460 – 37 T) was discussed. It was announced that consideration had been given to these methods as required by the regulations of the Society by Committee E-1 on Methods of Testing. As a result of certain questions concerning the glass apparatus used in these analytical procedures, Committee E-1 requested that action on the adoption of the methods be deferred. A motion for adoption as standard of the methods failed to receive the necessary two-thirds vote of those voting at the session and they will accordingly be continued as tentative.

The proposed revisions of the Tentative Specifications for Milled Toilet Soap (D 455 – 37 T), for Soda Ash (D 458 – 37 T), and Definitions of Terms Relating to Soaps and Detergents (D 459 – 37 T) were accepted, the specifications and definitions as revised being continued as tentative.

The Tentative Specifications for Caustic Soda (D 456 – 37 T), and for Modified Soda (Sesquicarbonate Type) (D 457 – 37 T) were approved for reference to letter ballot of the Society for adoption as standard.

The report of Committee D-13 on Textile Materials was presented by the chairman, H. J. Ball. The new Methods of Test for Fastness of Colored Textile Fabrics to Light, of Testing and Tolerances for Spun Rayon Yarns and Threads, of Testing and Tolerances for Yarns Spun from Wool Mixed with Fibers Other than Wool, and Specifications for Single-Ply Bleached Cotton Broadcloth, for Bleached Wide Cotton Sheeting, and for Terry (Turkish) Toweling were accepted for publication as tentative.

The proposed revisions of the Tentative Definitions and Terms Relating to Textile Materials (D 123 – 37 T), and Methods of Testing Pile Floor Covering (D 418 – 37 T), and Test for Wool Felt (D 461 – 37 T) were accepted, the definitions and methods as revised being continued as tentative.

The revisions proposed for immediate adoption in the Standard General Methods of Testing Woven Textile Fabrics (D 39 – 36), of Testing and Tolerances for Tire Cord, Woven and on Cones (D 179 – 33), of Testing and Tolerances for Woolen Yarns (D 403 – 36), and of Testing and Tolerances for Worsted Yarns (D 404 – 36) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed revisions of the Standard Specifications for Textile Testing Machines (D 76 – 37), of General Methods of Testing and Tolerances for Cotton

Yarns and Threads (D 180 - 37), of Testing and Tolerances for Cotton Sewing Threads (D 204 - 36), and Specifications and Methods of Test for Cotton Goods for Rubber and Pyroxylin Coating (D 334 - 34) were accepted for publication as tentative.

The Tentative Method of Test for Strength of Rayon Woven Fabric when Wet (D 415 - 35 T) was approved for reference to letter ballot of the Society for adoption as standard.

The withdrawal of the Standard Specifications for 23/5/3 Carded American Tire Cord (D 298 - 29) was approved. It was announced that the committee had decided to withdraw the recommendation to discontinue the Standard Specifications and Methods of Test for Osnaburg Cement Sacks (D 205 - 27) which appeared in the report as preprinted.

The Proposed Method for the Quantitative Determination of Tussah Silk in Mixtures with Other Fibers was accepted for publication as information.

A paper entitled "Progress in Wool Standardization,"[1] by G. E. Hopkins, was presented by title.

The report of Committee D-11 on Rubber Products was presented by the secretary, Arthur W. Carpenter. The new revised Methods for Testing Flat Rubber Belting were accepted to supersede immediately the present Standard Methods of Testing Rubber Belting Used for Power Transmission (D 378 - 36), with the following modification presented on the floor at the annual meeting, subject to favorable letter ballot of Committee D-11:[2]

Section 3.—Combine and revise the present paragraphs (*d*) and (*e*) from the form as preprinted: namely,

(*d*) *Thickness of Covers when $\frac{3}{64}$ in. or Over.*—The thickness of the top or bottom cover shall be taken as the minimum thickness found on the unbuffed cover sample from which the tension test specimen is prepared.

(*e*) *Thickness of Covers when less than $\frac{3}{64}$ in.*—The thickness of the top and bottom covers shall be the minimum thickness found on the test specimen prepared for the adhesion test and shall be determined as follows: The over-all thickness of the test specimen shall be measured. The rubber covers shall be stripped from the test specimen and the thickness of the carcass measured. The difference between these measurements will represent the thickness of the two covers which shall be considered as being uniformly distributed provided the fabric is thoroughly coated on the outside.

to read as follows:

(*d*) *Thickness of Covers.*—The thickness of the top or bottom cover shall be the minimum thickness found on the test specimen prepared for the adhesion test and shall be determined as follows: The over-all thickness of the test specimen shall first be measured. The rubber cover shall then be stripped from one surface and the thickness of the carcass, including the remaining cover, shall be measured. The difference between the first and second measurements will represent the thickness of the cover removed. The same procedure shall be followed on the test specimen from which the first cover has been removed, when the thickness of the other cover is required.

The proposed revisions of the Tentative Methods of Physical Testing of Rubber Products (General Requirements) (D 15 - 35 T), of Testing Rubber Hose (D 380 - 37 T), of Testing Rubber Insulated Wire and Cable (D 470 - 37 T), and Specifications for Rubber Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 - 37 T) were accepted, the methods and specifications as revised being continued as tentative.

The revisions proposed for immediate adoption in the Standard Methods of Chemical Analysis of Rubber Products (D 297 - 36) and Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 - 35) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

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[1] Published in ASTM BULLETIN, No. 93, August, 1938, p. 12.

[2] This recommendation was submitted to letter ballot of Committee D-11, which consists of 97 members; 56 members returned their ballots, of whom 38 voted affirmatively and 0 negatively.

The Tentative Specifications and Tests for Friction Tape for General Use for Electrical Purposes (D 69 – 36 T) and for Rubber Insulating Tape (D 119 – 35 T), as revised, were approved for reference to letter ballot of the Society for adoption as standard.

The report of Committee D-20 on Plastics was presented by the chairman, W. E. Emley.

A paper entitled "Rosin Crystallization (A Discussion of the Theory Underlying Crystallization)," by E. A. Georgi, was presented from manuscript by the author.

The report of Committee D-1 on Paint, Varnish, Lacquer, and Related Products was presented by the Secretary, M. Rea Paul. The proposed Tentative Specifications for Aluminum Pigment Paste for Paint, for C. P. Para Red Toner, for C. P. Zinc Yellow (Zinc Chromate), and of Test for Reactivity of Paint Liquids were accepted for publication as tentative. It was announced that the committee had decided to withdraw the recommendation for publication as tentative of the proposed Specifications for Interior Flat Paint (Oil or Varnish Base), Ready-Mixed and Semipaste, Light Tints and White, which appeared in the report as preprinted.

The proposed Tentative Specifications for Titanium Dioxide Pigments and for Zinc Sulfide Pigments were accepted for publication as tentative, with the following additional changes, presented on the floor at the annual meeting, subject to favorable letter ballot of Committee D-1:[1]

Section 3 (a).—Change from the form as preprinted to read as follows by the addition of the italicized words and the omission of those in brackets:

> 3. (*a*) In such physical properties as are specified by the purchaser, the pigment shall [be similar to, or at least equal to] *satisfactorily match* a reference sample mutually agreed upon by the purchaser and the seller.

In the table of requirements under Paragraph (*b*) change the third item to read as follows by the addition of the italicized word and figure: "Moisture and other matter volatile *at 105 C.*, max., per cent."

Section 5.—Change the first sentence to read as follows by the addition of the italicized word and the omission of that in brackets:

> All tests shall be conducted in accordance with the [standard] *current* methods of the American Society for Testing Materials.

Delete from this section the note which appeared in the specifications as preprinted referring to several methods of test.

The proposed Tentative Method of Sampling and Testing Aluminum Powder and Aluminum Paste were accepted for publication as tentative with the following additional changes presented on the floor at the annual meeting subject to favorable letter ballot of Committee D-1:[2]

Section 4.—Change the test for leafing properties from the form as preprinted to read as follows:

> 4. *Aluminum Powder.*—Stir vigorously, for at least 2 min., a mixture of the sample with a suitable vehicle (Note 2) in the ratio of 10 g. of Type *A* powder, or 5 g. of Type *B* powder to 40 ml. of the vehicle. The container shall be of such diameter that the free surface of the liquid will have an area within the limits of 25 to 50 sq. cm. Two minutes after cessation of the stirring, the entire free surface of the mixture shall have the appearance of a continuous, brilliant film, indicating satisfactory leafing properties.

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[1] These recommendations were submitted to letter ballot of Committee D-1, which consists of 215 members; 119 members returned their ballots with the following results: Specifications for Titanium Dioxide Pigments, 95 affirmative, 0 negative; Specifications for Zinc Sulfide Pigments, 91 affirmative, 0 negative.

[2] This recommendation was submitted to letter ballot of Committee D-1, which consists of 215 members; 119 members returned their ballots, of whom 85 voted affirmatively and 0 negatively.

NOTE 1.—The leafing test specified for aluminum powder is not satisfactory for aluminum paste, and another method is under development.

NOTE 2.—A varnish conforming to the Federal Specifications for Mixing Varnish for Aluminum Paint (TT-V-81) is suitable for this purpose. The small spatula used for stirring should be withdrawn, touching it once against the side of the container. The time should be noted and the container allowed to remain undisturbed and free of air currents for the 2-min. period.

The proposed revisions of the Tentative Methods of Routine Analysis of Dry Cuprous Oxide (D 283 - 37 T), and of Routine Analysis of Zinc Yellow Pigment (Zinc Chromate Yellow) (D 444 - 37 T) were accepted, the methods as revised being continued as tentative.

The revision proposed for immediate adoption in the Standard Specifications for Basic Carbonate White Lead (D 81 - 34) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed revisions of the Standard Specifications for Red Lead (D 83 - 31), for Commercial Para Red (D 264 - 28), for Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 - 31), each in the form of separate tentative specifications were accepted for publication. The proposed revisions of the Standard Specifications for Normal Butyl Acetate (88 to 92 per cent Grade) (D 303 - 33), for Butyl Propionate (90 to 93 per cent Grade) (D 320 - 33), and for Ethyl Lactate (Synthetic) (D 321 - 33), were accepted for publication as tentative.

The Tentative Specifications for Basic Sulfate White Lead (D 82 - 37 T), as revised, for Blue Lead; Basic Sulfate (D 405 - 35 T), as revised, for Wood to Be Used as Panels in Weather Tests of Paints and Varnishes (D 358 - 35 T), and Methods of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number) (D 154 - 35 T) were approved for reference to letter ballot of the Society for adoption as standard.

The withdrawal of the Standard Method of Test for Determination of Polishing Lubricant in Aluminum Powder for Paints (Aluminum Bronze Powder) (D 306 - 31) was approved.

A paper entitled "Adherence of Organic Coatings to Metals," by A. E. Schuh, was presented by C. C. Hipkins and discussed.

The report of Committee D-17 on Naval Stores was presented by the secretary, C. F. Speh. The new Methods of Sampling and Grading Rosin were accepted for publication as tentative. The editorial changes in the Standard Method of Test for Determination of Toluol Insoluble Matter in Rosin (Chiefly Sand, Chips, Dirt and Bark) (D 269 - 30) were accepted.

There being no further business the chairman then declared the Forty-first Annual Meeting adjourned *sine die.*

ORGANIZED RESEARCH

Annual Address by the President

Albert Easton White[1]

June 28, 1938

The development of standards and the promotion of knowledge of engineering materials are the major functions of the American Society for Testing Materials. With respect to this latter function—the promotion of knowledge of engineering materials—the A.S.T.M. Year Book states that "it is carried on through investigations and researches by its committees, through the collection and publication of data on various subjects, and through the presentation and discussion of papers on the properties and tests of materials." Some fifty active projects on the properties of materials are under investigation by various committees of the Society, and over seventy other investigations are being carried forward on methods of testing. "The volume and importance of this work have led to the organization of a standing committee on research, whose functions, primarily, are the correlation of all the research activities within the Society and the study of means by which the Society may further develop the extension of the field of knowledge of engineering materials."

In view, therefore, of the recognized importance of this field, it seems most appropriate that your President take as his subject for the annual address, "Organized Research."

It would not be possible in an address of this type to set forth all of the agencies engaged in research. The list would be too long, for it would run into the thousands. In fact, if all of the individuals engaged in this type of work were taken into consideration, it would doubtless run into several hundred thousand. Nor is it possible, with any degree of accuracy, to set forth the amount spent annually for research. Without calling upon one's imagination, the amount used for this purpose is well into the hundreds of millions of dollars annually.

Recognizing at the start the many ramifications of research and the large expenditures involved, it is believed that most of the activities in this field can be placed in ten groups. These are as follows: Individuals, corporations, associations, testing laboratories, Government bureaus, councils, foundations, societies, research institutes, and colleges and universities. Each of these groups will be discussed somewhat in detail.

Individuals:

Previous to the beginning of the twentieth century, a considerable amount of the research work in the world was done by individuals. These men carried forward their work, spurred on by an undying enthusiasm for their respective subjects. Many of them were engaged in lines of endeavor to improve the well-being of their fellows: for instance, Eli Whitney in inventing the cotton gin, and Charles Goodyear in developing rubber into a useful product. Too important to go unmentioned in this list of great scientists are such persons as Samuel Morse in his pioneer work in the field of telegraphy, Thomas A. Edison, Alexander Bell in his work on the telephone, and Prof. Elihu Thompson in his work in the field of electricity leading, as it did, to the founding of the General Electric Co.

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[1] Director of Department of Engineering Research, and Professor of Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

These are but a few of many who contributed materially through research to the field of applied science. Yet, while these men were achieving such signal success in the field of applied research, there were many others, in large measure located in our universities, who were making important contributions in the field of fundamental science. In fact, without the findings of these latter individuals, practically all of our modern research activity would be at a standstill, because all applied research is built on foundations of fundamental research.

The work of individuals is just as important today as it was previous to the beginning of the twentieth century, for here and there individuals come forward in the field of applied research with findings which have escaped those engaged through organized bureaus. Also, it is equally important that ways and means be found for individuals engaged in our colleges and universities to carry on fundamental research, for, unless work of this type goes forward, we may expect applied research to become stagnant in the next decade.

Corporations:

The major amount of industrial research in this country is now done by corporations. This fact is so self-evident and so well recognized that it needs no support. The American Telephone and Telegraph Co., for instance, spends over eight million dollars annually, in this field. Large sums are set aside for the sponsorship and support of research work by such companies as the General Electric Co., Westinghouse Electric and Manufacturing Co., E. I. du Pont de Nemours and Co., General Motors Corp., Chrysler Corp., Ford Motor Co., United States Steel Corp., Bethlehem Steel Co., Inc., The Dow Chemical Co., The Detroit Edison Co., and others too numerous to mention. These concerns are active, not only in the field of applied research, but also in many cases in the field of fundamental research. In fact, a number of these organizations have aided greatly in the advancement of medicine as a result of the work which was done in their laboratories.

Much of this work is so highly organized that in many instances a number of individuals are working on different aspects of the same problem. In a few cases some of the work is essentially individualistic in that an investigator is given a problem and a place in which to work it out without contact with his associates, unless he so desires. In a few instances a limited number of individuals are given even greater freedom by being informed that they may work on such problems as they think will be for the best interests of science and of the company which they represent. This condition may be viewed as a far cry from organized research, and yet it has resulted in some of the highest types of research work which has been done in this country. To be sure, such latitude must be given with discretion, and only to those whose ability for productive research has been previously demonstrated.

Corporations should, when organizing

a research department, keep in mind the fact that it must be carefully planned and its growth should, in most cases, be relatively slow. One cannot expect successful research activities by providing buildings and equipment without thought of the personnel. It is necessary to study each individual carefully when forming such a group, for successful research workers are temperamental and can give their best only when they fit into such an organization.

As a rule, most of our corporations carry forward their research activities in one of three ways. Some maintain their own organization and do not place any of their research problems elsewhere. Others have their own research organizations but allocate certain special problems to other organizations. Still others place most of their work with other agencies engaged in research, doing in their own plant only work which they consider of a control character. No brief will be presented for any one of these three methods. Each has its advantages. There does, however, appear to be a definite trend for corporations to place part of their research problems with agencies other than their own.

No matter how large or how small a corporation, it must look forward to supporting research work if it expects to continue long in the field in which it is at present engaged. The larger corporation can determine along which of the three ways it will proceed. It is usually inadvisable for the smaller corporation, at least at the start, to establish and maintain a research organization of its own. There is no need to do so, for there are at present plenty of well-organized facilities and personnel available to which they can take their problems. This is doubtless more true today than it was a few years ago and, therefore, with proper care in the selection of research facilities, the smaller corporations can carry forward their programs as well as can the large corporations.

Associations:

Various trade associations have been organized for the purpose of carrying forward work on matters which are of mutual interest. Research is frequently one of these activities. Such work has led in numerous instances to an improvement in the products of the members of the respective associations. Some of these cooperative groups are the Warm Air Heating and Ventilating Association, which has done much to improve household heating of this type, the Malleable Iron Research Institute, the Portland Cement Association under whose sponsorship marked improvement has taken place in the mixing of concrete, the National Sand and Gravel Association, the Calcium Chloride Association, and many others.

It is usually customary for these associations to have a research committee and, through funds which are made available to it, sponsor one or more research projects.

Testing Laboratories:

There are, scattered throughout the country, a considerable number of companies known as testing laboratories. These laboratories, possibly, were organized in the early days for the purpose of testing and inspecting engineering materials. Some of them have outgrown this stage in their development and probably a broader term for their activities should be employed. Many of them do research work of a high order and their activity in this field should be recognized.

Government Bureaus:

The Government maintains two outstanding bureaus in the field of engineering materials. These are the Bureau of

Standards and the Bureau of Mines. Although one of the principal functions of the Bureau of Standards is to create and develop standards for use throughout the nation, it is now engaged in a large variety of activities in the field of research, a number of which are sponsored by industry.

The Bureau of Mines, as its name indicates, deals with minerals and mineral products. It has done and is still doing a great piece of work with respect to fuels and, through its various stations throughout the country, is engaged in working out proper methods of extraction for various ores and minerals.

Also, a great deal of research work is done for the Government at the Naval Engineering Experiment Station, at the United States Air Corps Station at Dayton, and at Watertown Arsenal.

There are, of course, many other Government bureaus carrying on research, but these have been mentioned as the leading ones dealing with engineering materials.

Councils:

There is but one major council engaged in research activities. This is the National Research Council. Its work, however, is so varied and widespread that it is felt it should be included in the list of agencies through which research work is carried forward. It operates in many fields, of which engineering is one. It carries on most of its work by making grants to various agencies in a position to do research. Many of its grants are given to universities and colleges. It is the recognized national agency for the correlation of research.

Foundations:

There are several hundred foundations in this country engaged in the sponsorship of research. Among these are the Carnegie Institution, the Smithsonian Institution, and the Rockefeller Foundations. These function mainly in the fields of physical science, social science, and medicine. They have all rendered outstanding service in the field of fundamental scientific research. The Rockefeller Foundations have been notable for the aid they have given to needy institutions and for the contributions which their investigators have made in the field of medicine. In most instances, grants for research programs are made by the various foundations on the basis of the object for which the foundation was established, and then on the basis of greatest needs in these respective fields. This results in grants being fairly wide spread and, particularly in the case of the Rockefeller Foundations, in being world wide.

An outstanding agency tied in intimately with the four founder engineering societies is the Engineering Foundation. Effective work for this Foundation was made possible by a large endowment given by Ambrose Swasey and subsequent gifts. Requests for grants from this Foundation come largely from the respective research committees of the founder societies. When approved, it is customary to make nominal grants in order to start the work or to assist in the procurement of funds from interested sources in order that the proposed program may go forward on an adequate basis.

Societies:

It has been the practice for nearly all of our national societies to sponsor research work to as great an extent as possible. At least, if they do not find it within their power to support work, they encourage it in every way possible and lend their assistance to those who seek financial aid. In fact, the life blood of any society of national importance is research activity. There would be little need for engineering societies, were their activities confined solely to social gatherings, however much we recognize and appreciate the importance of social contacts.

A number of societies have research committees which serve as correlating agencies for research. Special committees are formed for special purposes. These special committees, in turn, seek financial aid from time to time for the work which they are following. This work is then usually placed at suitable institutions. In addition, many of these committees conduct research work without any outside financial assistance by encouraging those who are willing to undertake special aspects of a particular problem. The committees then serve essentially as correlating agencies and in many instances splendid results have accrued.

As examples of research activities which have been splendidly performed by societies, reference should be made to the work in welding carried forward by the American Welding Society, the work on steam tables and elevator cables by The American Society of Mechanical Engineers, the work on corrosion and fatigue sponsored by our Society, the work of the Joint Research Committee on Effect of Temperature on the Properties of Metals sponsored jointly by our Society and The American Society of Mechanical Engineers, and the work on boiler feedwater studies which has been sponsored by six technical organizations.

These are but a few of several hundred investigations which have been sponsored by these and other technical societies.

Research Institutes:

In the field of research institutes, the two outstanding endowed ones functioning in engineering are Mellon Institute and Battelle Memorial Institute.

Mellon Institute has been in operation for about twenty-five years and Battelle for about ten years. Through the generosity of those who established them, they have buildings and facilities and an endowment to assist in their operation. In the case of Mellon Institute, work on any problem is done by a fellow with as many assistants as may be necessary. He reports to one of a number of assistant directors, who, in turn, report to the Director.

A somewhat similar type of organization is followed at Battelle. Both of these institutions do work for corporations which may or may not have research laboratories of their own. Likewise, they do work for individuals and groups. The growth and expansion of these two institutes is an indication of the soundness of their organization.

Colleges and Universities:

Research work in our colleges and universities is done in one of two ways: either as individual activity, or as part of a sponsored plan.

In the field of individual activity, it is well recognized that practically all colleges and universities encourage the members of their faculties to engage in research in their particular fields of specialization. In fact, criticism has been raised in some quarters that too much emphasis has been placed on research by the administrative officers of our schools and colleges. The claim is made that too much research work detracts from teaching. It is questionable if this contention is generally sound, particularly for those engaged in the teaching of science. Usually those who have no longer an interest in research have become stagnant and their claim that their teaching takes all of their energy and they have no time available for research is but a subterfuge. In fact, the standing and reputation of a college or university is intimately tied up with the productivity of its faculty in the field of research. No college or university can hope to go forward if the faculty members fail to be active in research work. It is of importance, therefore, that all possible assistance be given to faculty members in their personal research interests.

With respect to the sponsored plan, the procedure followed is usually along one of three lines.

In the first instance, a grant may be made to a faculty man for the support of a definite research program. This grant may be made by the school itself or by an outside agency. Also closely analogous to this condition is, the employment with continuous tenure of a person for research.

A second type is that carried forward in our schools or colleges in agriculture and mechanical arts. To these institutions substantial grants are made by the Government, supported in many instances by grants from the states themselves. The work thus encouraged and supported has been of particular benefit and value to the agricultural interests.

The third and most recent development has been the establishment of engineering research activities. Much worthwhile work has been done in this field by schools like the Massachusetts Institute of Technology and a number of our state universities, such as the University of Illinois, Purdue University, Ohio State University, the University of Minnesota, and the University of Michigan. Other schools and colleges have initiated work in this field, so that activity in this line is on the increase. The directors of these departments are either deans or are closely associated with the deans. Some schools have appreciable grants which make it possible for them to carry forward a properly supported program of research in the fundamental sciences. All of them have arrangements whereby they may conduct research for individuals, corporations, foundations, societies, and others, when funds for such work are provided. This work has been of outstanding benefit to the colleges and universities in which it has been done in that it assists in keeping the members of the faculty active and in a position of leadership in their respective fields.

Research is one of the keystones upon which further world progress depends. It enters into the field of agriculture, communication, transportation, public health, energy, and the production of industrial products. There is a definite interlocking of all of these groups. Each one is dependent for its prosperity and advancement upon the others. All must look to research as one of their foundation stones.

Without communication and transportation, agriculture would be stifled. Without advance in public health, the lives of the producers and consumers of agricultural products would be jeopardized. Without the use of energy in our tractors, motors, and other power-producing agencies, the development of our agricultural fields would be reduced to a degree that would fill even those who preach the philosophy of scarcity with grave alarm. Without converting many of their agricultural products or by-products into the channels of industry, dire waste would result and the world would be deprived of products which have virtually become necessities in our present-day life.

Just as agriculture is dependent upon all of the other fields of activity, so is each one, in turn, dependent upon the others. The well-being of one requires the well-being of the others.

The "handwriting on the wall" is clear. The findings of research are needed for our continued progress and prosperity. No field is an exception. Sponsorship of research, therefore, must and will be continued at an ever accelerating rate. Such sponsorship must be in the fields of both fundamental and applied research. Without the former, little ultimate progress can take place in the latter. Without the latter, little benefit can result to mankind from the former. Every encouragement, therefore, should be given to those individuals and agencies engaged in research so that, through their achievements, research may contribute its share in restoring prosperity, improving standards of living, and adding to our store of cultural values.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The Executive Committee offers the following report on general Society activities for the year ending with this annual meeting:

Membership:

The membership of the Society on June 1, 1938, was 4156. Statistics showing gains and losses in the various classes of membership are as follows:

Class of Membership	Membership		Losses				Additions		Total		
	June 1, 1937	June 1, 1938	Resignations	Dropped	Death	Transfer	Transfer	Election	Loss	Gain	Increase
Honorary	1	3	...	...	1	..	1	2	1	3	2
Life or Perpetuity	10	10	...	...	...	...	...	...	...	...	...
Sustaining	11	12	...	...	...	...	1	...	...	1	1
Company, Firm, etc.	982	1016	28	5	...	1	7	61	34	68	34
Individual, etc.	2933	3062	100	35	27	8	11	288	170	299	129
Junior	55	53	3	6	...	11	...	18	20	18	2[a]
Total	3992	4156	131	46	28	20	20	369	225	389	164
Student	282	331	40	113	...	5	...	207	158	207	49

[a] Loss.

The net gain for the year of 164 compares with 251 for the preceding year and 129 for two years ago. Losses from resignations and delinquencies were, by a coincidence, exactly the same as reported a year ago, namely, 177. Elections to membership, however, show a decrease, 369 compared to 454. Industrial conditions for the past six months are partly responsible for this decrease. The membership record for the year as a whole is most satisfactory and brings us substantially nearer the 1930 membership peak of 4400. The number of student members increased from 282 to 331.

The Carnegie-Illinois Steel Corp. acquired a sustaining membership as of January 1, 1938, bringing the total of such members to twelve.

As announced at the annual meeting last year, the Executive Committee elected three honorary members, each a past-president of the Society, namely, J. A. Capp, G. H. Clamer and G. W. Thompson. Three new honorary members were recently elected, of which formal announcement will be made at the present meeting.

New membership work continues actively with the help and cooperation of many members of the Society and of the several district committees, for which the Executive Committee expresses its sincere appreciation.

The Society has lost the following members through death:

	DATE OF MEMBERSHIP
Bateman, Ernest	1914
Bolton, Thomas	1925
Boyd, Gilbert D	1936
Browne, Herbert R	1930
Bull, R. A	1908
Bunker, H. M	1931
Capp, J. A	1898
Church, Sumner R	1907
Dolph, John C	1923
Eddy, Harrison P	1910
Galbraith, Lawrence	1931
Ginder, J. W	1924
Giroux, Gustave	1904

	DATE OF MEMBERSHIP
Gray, George William	1913
Gulick, Henry	1907
Hippensteel, C. L.	1927
Howard, Leslie E.	1903
Jewett, J. Y.	1900
Lukens, Alan N.	1905
McLaren, W. F.	1923
Ostrom, John Nelson	1903
Ritter, Daniel E.	1909
Rohde, O. C.	1919
Sargent, Fitz William	1908
Strauss, Joseph	1919
van der Waerden, H.	1922
Waddell, J. A. L.	1896
Warnock, Charles	1926

Among these are a number who had taken an active part in the Society's affairs. J. A. Capp, Past-President and Honorary Member, was an outstanding leader, serving the Society for forty years in its technical work in many fields and in important administrative and executive capacities. All who have worked with him will cherish that association and his life will be an inspiration to them as they carry on the work he himself so ably performed. Ernest Bateman, R. A. Bull, S. R. Church, J. W. Ginder, G. W. Gray, C. L. Hippensteel, L. E. Howard and A. N. Lukens were for many years actively engaged in the committee work of the Society, holding responsible office and contributing much to the advancement of the Society's work.

Committee Activities:

The work of the committees during this past year is recorded in their annual reports to the Society, which evidence the usual activity. The reports of Committees E-9 on Research and E-10 on Standards deal with certain phases of the committee work, and, supplemented by reviews that will appear in the August and October issues of the *ASTM Bulletin*, give a general summary of these activities. This report, therefore, will deal only with certain administrative matters concerning the standing committees.

The merger of Committees C-3 on Brick and C-10 on Hollow Masonry Building Units, the reasons for which were explained in the Executive Committee report a year ago, was accomplished by a formal organization meeting of the new Committee C-15 on Manufactured Masonry Units held during the annual meeting in 1937, at which D. E. Parsons was elected chairman.

Upon the recommendation of Committee D-15 on Thermometers and Laboratory Glassware, that committee was discontinued as a separate standing committee and responsibility for this field of work was taken over by Committee E-1 on Methods of Testing. It was felt that because the work of D-15 was very largely devoted to the preparation of specifications for glassware and thermometers for use by other A.S.T.M. committees, the intercommittee activities thus involved could be handled more efficiently under Committee E-1, since one of the principal functions of the latter committee is to aid and advise the standing committees in matters relating to standard methods and instruments of testing. Moreover, as a technical committee of Committee E-1 the membership could be more readily expanded to take care of special problems concerning apparatus as they arise in the other Society committees. Committee E-1 has accordingly organized a new Technical Committee XII on Laboratory Glassware, comprising the membership of Committee D-15 with certain additions. The officers of Committee D-15 continue as officers of the new technical committee.

Committee D-14 on Screen Wire Cloth, organized in 1920, which a few years ago completed in cooperation with the National Bureau of Standards an extensive study of atmospheric corrosion of various types of non-ferrous insect screen cloth, requested about a year ago that it be discharged since it had completed the work that lay before it. The committee also recommended that the Standard Specifications for Non-Ferrous Insect Screen Cloth (B 50 - 29), which it had written, be withdrawn inasmuch as the specifications were obsolete and it was not believed necessary for the Society to maintain a specification for this product. After examining into the recommendations of the committee and particularly reviewing the status of the specifications, the Executive Committee decided to discharge the committee with appreciation of its services and to withdraw the specifications.

Several years ago Committee C-12 on Mortars for Unit Masonry was disbanded because of a number of difficulties that arose, resulting in the inability of the committee to make substantial progress in its work. The interest of many members and organizations in the testing and specifying of mortars has not diminished. Accordingly about a year ago the Executive Committee authorized the reorganization of the committee and on November 4, 1937, at a meeting in Washington the committee was formally reorganized under the chairmanship of J. W. McBurney. An account of this meeting was published in the December, 1937, *Bulletin.* The committee has adopted the following statement of the present scope of its work:

> *Scope.*—Preparation of specifications, methods of testing and definitions relating to mortars for use with units of burned clay or shale, sand-lime, concrete and stone and similar materials used in unit masonry, other than those intended for use as refractories. Development of specifications for cementitious materials is not included in the scope of the committee.

At the last annual meeting, three new committees of the Society were organized, the steps leading up to this expansion of the Society's work having been mentioned in the Executive Committee's report of last year: Committee C-14 on Glass and Glass Products, G. W. Morey, chairman; Committee D-6 on Paper and Paper Products, Roger C. Griffin, chairman; Committee D-20 on Plastics, W. E. Emley, chairman. The scopes of the three committees are published in the Society Year Book. Each of the committees has made a splendid start in the work assigned to it.

In addition, two other new committees were formed during the year. Committee C-16 on Thermal Insulating Materials was organized in Rochester on March 9, under the temporary chairmanship of J. H. Walker. This represents the culmination of discussions that have taken place over a period of years looking to the desirability of the Society undertaking work in the field of thermal insulation, apart from that now being carried out by Committee C-8 on Refractories. The latter committee includes within its scope the so-called high-temperature insulations; the new committee will undertake work on insulations for use at somewhat lower temperatures, for example in the piping field and similar type industrial insulation. An account of the organization meeting appeared in the March, 1938, *Bulletin.* Great interest has already been shown in the work this committee is undertaking.

The Symposium on Radiography and X-ray Diffraction Methods held at the annual meeting in 1936 made clear the increasing need for research and standardization work on important problems in the field of radiography. In order more effectively to carry out this work, which heretofore has been under the jurisdiction of Committee E-4 on Metallography, it was decided, with the approval of the latter committee, to create a new standing committee, which has been designated Committee E-7 on Radiographic Testing. Formal organization was accomplished at a meeting in New York City on February 14, at which H. H. Lester was elected chairman. The second meeting was held in March at Rochester, at which subcommittee organization was perfected and work begun on certain projects. An account of the meeting appeared in the March, 1938, *Bulletin.*

In accordance with the decision announced a year ago, there was published in the 1937 Year Book a brief statement of scope for each standing committee. These statements are serving a very useful purpose, and in several instances have directed attention to overlapping in the scopes of certain committees. Several such jurisdictional questions were adjusted during the year by the Executive Committee in consultation with the standing committees concerned.

The importance of periodic review of standards is obvious, and especially so in the case of standards that have stood for a number of years without revision and may no longer be in accord with present practice. The provision of the Regulations Governing Standing Committees requiring committees to review all standards that have stood without revision for six or more years prior to the year of triennial publication of the Book of Standards was written with these considerations in mind. Such reviews are now being made by the committees of the Society in anticipation of the publication of the 1939 Book of Standards, so that any revisions found to be desirable can be proposed this year for publication as tentative in accordance with normal procedure.

The up-to-dateness of a committee's work may be considered from two angles: First, are the standards under the jurisdiction of a committee up to date? Second, has the committee prepared all the standards needed in the assigned field? While the reviews just mentioned are primarily concerned with the first aspect, failure of a committee to provide necessary standards in its assigned field may be fully as serious as failure to keep existing standards up to date. The Executive Committee is examining the committee work of the Society from both viewpoints.

Administrative Regulations:

Two modifications of the Regulations Governing Standing Committees have been agreed upon jointly by the Executive Committee and Committee E-5 on Standing Committees and are announced in this report with the intention that they shall become effective at the close of the present annual meeting.

The first is the addition of a new paragraph (*f*) to Section 2 on "Membership and Classifications," reading as follows:

> (*f*) Membership on a standing committee may be terminated by that committee for inactivity or for any other reason.

and the relettering of present paragraphs (*f*), (*g*) and (*h*) as (*g*), (*h*) and (*i*) respectively. It was felt that the present requirements are somewhat inadequate with regard to the termination of committee membership, although the supplementary regulations of the individual standing committees are intended to contain provisions covering the suspension of inactive members.

The second change is with respect to Section 19 dealing with "Advance Distributions of Reports." This section is being revised to read as indicated below by the addition of the words in italics and the omission of those in brackets:

> The annual reports of the standing committees shall be transmitted to the Secretary-Treasurer of the Society as early in the calendar year as possible, [and] *preferably* not less than eight weeks in advance of the date of the annual meeting. Preprints of [these] reports shall be mailed by the Secretary-Treasurer to every member of the Society who has signified his desire to receive such reports, [at the earliest possible subsequent date] *as early as practicable* and *preferably* not less than four weeks [before] *in advance of* the annual meeting, [so that members may come to the meeting prepared to discuss such reports and that members not intending to be

present at the meeting may contribute discussions by letter] *to facilitate prepared discussion either oral or by letter.*

Reports received between annual meetings shall be mailed by the Secretary-Treasurer to every member of the Society who has signified his desire to receive such reports.

The significant change is the modification of the specific requirement that reports must be submitted to the Secretary-Treasurer eight weeks in advance of the annual meeting and must be distributed four weeks in advance. It is not always possible to adhere strictly to this requirement, and any report not distributed four weeks in advance of the meeting is, under the present regulations, open to challenge on a technicality. It is desired to avoid this situation and yet at the same time indicate the importance of distributing reports in advance of the meeting. It is believed that the standing committees will just as earnestly continue their efforts to submit manuscripts of their reports in time to permit advance distribution.

As a result of consideration of certain difficulties that developed in the conduct of ballots in standing committees, it is believed to be desirable that in those cases where two or more persons represent a company membership on a standing committee the company should designate one of them as the voting representative. However, Committee E-5 and the Executive Committee have agreed that it is not necessary, at least for the present, to make this a mandatory requirement of the Regulations Governing Standing Committees, so the handling of such matters is left to the discretion of the individual standing committees.

Committee E-5 and the Executive Committee are also studying the provisions of the By-laws and Regulations Governing Standing Committees defining the procedure for the adoption of standards and tentative standards, and revisions thereof, at the annual meeting.

The Executive Committee has also approved revisions of the Regulations Governing Papers, Committee Reports and Discussions that were drawn up by Committee E-6 on Papers and Publications. These regulations have stood for over twenty years without revision, but changes in Society practice with respect to meetings and publications, notably the holding of regional meetings and the publication of technical papers and reports in the *Bulletin*, made it desirable that these regulations be brought up to date. The form and arrangement of the regulations have at the same time been improved. One of the more important changes is the provision that no paper will be accepted for inclusion on the program of a regional or annual meeting of the Society, manuscript of which is not in the hands of the Committee on Papers and Publications at least three weeks in advance of the meeting. It is further provided that in case a paper is for any reason not preprinted, a summary of it shall be made available. The revised Regulations will be published in the 1938 Year Book.

District Committees:

The district committees have continued their work in the interest of the Society. Their activities have been reported currently in the *Bulletin*, including an account of local meetings held under their sponsorship, of which brief mention is made in the following section of this report. Other activities include membership work, in which the district committees have been extremely helpful.

The second conference of officers of district committees was held during the Regional Meeting at Rochester in March, 1938, and a number of questions of common interest were discussed.

The Executive Committee wishes to express its appreciation to the officers and members of the district committees, who are devoting much time and thought to strengthening the Society's work and extending its usefulness throughout the regions in which these committees are functioning. The value of the services they are rendering can hardly be overestimated.

Meetings:

The various meetings held during the past year have been so fully reported in the Society *Bulletin* that it is necessary here simply to cite them as a matter of official record, with an expression of appreciation from the Executive Committee to the many members and committees who helped to make these meetings so successful.

The ninth Regional Meeting and the spring group meetings of committees held at Rochester, March 7 to 11, 1938, featured a Symposium on Plastics and enjoyed the largest attendance since these regional meetings were instituted. The total registration was 662, with upwards of 165 committee, subcommittee and section meetings.

The following meetings were held under the auspices of the respective district committees:

In New York on December 2, 1937, at which Foster Dee Snell spoke on "Some Factors in Detergency."

In Chicago a joint dinner meeting with the Chicago Section of the American Institute of Mining and Metallurgical Engineers on December 8, 1937, at which Past-President A. C. Fieldner spoke on "Fuels of Today and Tomorrow." Also in Chicago a dinner meeting on April 22, 1938, at which the principal address was by President A. E. White on the subject "Dividends from Research."

In Pittsburgh on March 18, at which President White was the guest of honor, the principal speaker being Judge Ralph H. Smith who spoke on "Behaviorism and Crime." The meeting was held at Mellon Institute and was followed by an interesting inspection of the Institute.

A dinner meeting in Detroit on April 19, followed by a symposium of four papers on the subject "Protecting Metals Against Corrosion."

A dinner meeting in Cleveland on May 5 at which Inspector David L. Cowles spoke on the role of testing in crime detection.

The President attended all of these meetings, save the first of the two Chicago meetings, and brought appropriate greetings from the Society to the members and guests present. It is hardly necessary to emphasize the value of such meetings and their importance in supporting the work of the Society and extending knowledge of its activities.

As to meetings during the coming year, the Executive Committee announces that the Regional Meeting next March will be held at Columbus, Ohio. The 1939 Annual Meeting, with the Fifth Exhibit of Testing Apparatus and Equipment, will be held at Atlantic City, June 26 to 30, this choice having been partly determined by the desirability of holding the meeting that year conveniently near the New York Worlds Fair. The Executive Committee is also considering plans for a regional meeting of the Society next year in San Francisco during the Golden Gate Exposition, upon invitation of the Northern California District Committee. The date in mind is the week of July 10, 1939, at which time several of the national engineering societies are planning to meet. Further announcement of all these meetings will appear in forthcoming issues of the *Bulletin*.

Publications:

The publications of the Society are the tangible result of the work of the committees and of those who offer papers and discussions for its meetings, and in the very nature of things they represent the most important single activity of the Society.

During the year the following regular publications were issued and distributed to the members:

1937 Proceedings: Part I (Committee Reports), 1379 pages; Part II (Technical Papers), 713 pages; total 2092 pages, 4600 copies each part; in addition to preprints of reports and papers totaling approximately 1258 pages.

1937 Supplement to Book of A.S.T.M. Standards, 282 pages, 9200 copies.

A.S.T.M. Methods of Chemical Analyses of Metals (second printing), 260 pages, 1000 copies.

1938 Index to A.S.T.M. Standards and Tentative Standards, 128 pages, 13,000 copies.

Year Book, 272 pages, 3000 copies.

ASTM Bulletin, 6 issues, 288 total pages, average edition, 6550.

The Book of A.S.T.M. Tentative Standards (1664 pages, 2200 copies) and the two symposiums at the Chicago Regional Meeting in March, 1937—the one on Lubricants (95 pages, 3000 copies) and the other on Corrosion Testing Procedures (137 pages, 1500 copies)—were published and furnished to members on order.

A comparative statement of the volume of the above-mentioned publications for the past four years follows:

Publication	1934, Pages	1935, Pages	1936, Pages	1937, Pages
Proceedings	2288	2279	2111	2092
Book of A.S.T.M. Standards	....	....	2419	....
Supplement to Book of A.S.T.M. Standards	224	216	....	282
A.S.T.M. Methods of Chemical Analyses of Metals	....	....	260	260
Index to A.S.T.M. Standards and Tentative Standards	....[a]	142	160	120
Year Book	251	256	246	272
Book of A.S.T.M. Tentative Standards	1288	1628	1422	1664
Regional Meeting Symposiums	119	156	132	232
Report on Significance of Tests of Concrete and Concrete Aggregates	127	....	....	....
	4297	4677	6750	4922

[a] Date of publication of Index changed to January 1 of succeeding year.

During the past year the Society also published the following compilations of standards:

Selected A.S.T.M. Standards for Students in Engineering, fifth edition, 224 pages, 4000 copies.

A.S.T.M. Standards on Cement (Committee C-1), 100 pages, 2750 copies, new compilation.

Manual of A.S.T.M. Standards on Refractory Materials (Committee C-8), 186 pages, 2500 copies, published biennially.

A.S.T.M. Standards on Petroleum Products and Lubricants (Committee D-2), 391 pages, 4250 copies, published annually.

A.S.T.M. Standards on Electrical Insulating Materials (Committee D-9), 381 pages, 700 copies, published annually.

A.S.T.M. Standards on Rubber Products (Committee D-11), 244 pages, 1250 copies, published biennially.

A.S.T.M. Standards on Textile Materials (Committee D-13), 314 pages, 1500 copies, published annually.

Of these, the compilation of Standards on Cement is a new publication and the demand for it is such that it may be published hereafter annually.

Two other compilations of standards complete this series, namely, those dealing with Coal and Coke (Committee D-5) published in 1936 and Paints (Committee D-1) last published in 1935. Other reports and special publications printed since the last annual meeting include:

Symposium on Motor Lubricants (reprint of 1933 publication), 121 pages, 1000 copies.

Report of Committee A-5 on Corrosion of Iron and Steel, 46 pages, 1000 copies.

Marburg Lecture: "Plastics—Some Applications and Methods of Testing," by T. Smith Taylor, 17 pages, 1000 copies.

Report of Committee B-6 on Die-Cast Metals and Alloys, 47 pages, 1000 copies.

Significance of Tests of Petroleum Products, 80 pages, 5000 copies.

Symposium on Wear of Metals (Philadelphia District Meeting, April, 1937), 111 pages, 1200 copies.

Viscosity-Temperature Charts: Chart A, 21,450 copies; Chart B, 19,750 copies; Chart C, 8092; Chart D, 5000 copies.

Symposium on Significance of Tests of Coal, 128 pages, 2500 copies.

Symposium on Correlation Between Accelerated Laboratory Tests and Service Tests on Protective and Decorative Coatings, 55 pages, 2500 copies.

Symposium on Consistency: Critical Discussion on Present-Day Practices in Consistency Measurement, 79 pages, 750 copies.

Symposium on Plastics (Rochester Regional Meeting, March 9, 1938), 57 pages, 2000 copies.

The policy of including technical papers in the *Bulletin* has been continued and an increase in the budget for this purpose has made it possible to publish a number of important technical contributions, including several papers presented at district and committee meetings and at least one extensive committee report. With the marked increase in the size of the *Bulletin* it was found to be advisable to enter it as second class mail matter, which greatly decreases the cost of mailing but requires that the publication be put upon a subscription basis, which has been done.

The subscription price is $1.50 a year; for members this is included in their annual dues. Many non-members are now receiving the *Bulletin* as subscribers. In this way they are following important activities in standardization and research as covered in *Bulletin* news articles, keeping in touch periodically with Society developments and having on file the technical papers and reports which are included.

Committee E-6 on Papers and Publications is making a thorough study of the typesetting and format of the Society publications. The advantages of the double-column page in readability, decreased thickness of books and a net saving in cost, led to its adoption several years ago for some of the special publications, such as the various regional meeting symposiums. Last year the technical papers and discussions that comprise Part II of the *Proceedings* were set in this style and the response has been so favorable that committee reports are also being set in that style this year. The adaptation of the double-column format to the standards of the Society involves a number of problems that are being carefully studied.

Finances:

Report for the Fiscal Year 1937.—The annual statement of the finances of the Society follows in the report of the auditors for the fiscal year, January 1 to December 31, 1937. The report gives the balance sheet of assets and liabilities, including special and designated funds (that is, the Research Fund, Medal and Lecture Fund, and Committee Funds); statement of receipts and disbursements, in which the items are classified into "operating" (budgeted) and "non-operating"; details of special funds; and investment of Society funds, both book and market values being given.

Total receipts from dues and entrance fees in 1937 were $79,924.67, an increase over receipts for the preceding year of about $5200. This, of course, is a reflection of the gratifying growth of membership during 1937.

Receipts from sales of publications reached by far the highest figure in the Society's history, namely, $66,767.85. Greatly increased sales of standards and tentative standards, both in book form and as separate reprints, contributed largely to this splendid showing, although increased sales of all of the Society's publications featured last year's operations. It is significant that income from this source was 40 per cent of total income, compared to an average of about 33 per cent for the three preceding years. The intrinsic value of the Society's publications and the growing demand for them constitutes one of its most valuable assets.

Miscellaneous receipts amounted to $19,820.09, which includes substantially increased income from advertising in the *Bulletin*, and the receipts from sale of space in the Exhibit. Receipts from advertising in the *Bulletin* were substantially higher than in 1936 and were sufficient to meet the increased publication costs of the *Bulletin* due to its expansion, with a favorable balance of nearly $500.

Total operating receipts were $166,512.61. Total operating disbursements with all current bills paid, as detailed in the auditors' report, were $146,527.80, leaving a favorable balance between operating receipts and operating disbursements of $19,984.81. Of this amount $6000 was placed in reserve for publication of the 1939 Book of Standards, leaving a net balance of $13,984.81, which has been added to the reserve funds of the Society.

The following amounts were drawn during the year from surplus for the purposes stated: (1) $2000 transferred to the Headquarters Fund, to begin provision for possible extraordinary expenses in the future in relation to the maintenance of suitable Society headquarters; (2) $2500 transferred to the principal of the A.S.T.M. Research Fund, representing part of the entrance fees in recent years which had been temporarily held in a contingency reserve fund; and (3) $1000 contributed towards the deficit of the International Association for Testing Materials, as explained in the report last year. Thus, general surplus was reduced $5500 by these transactions, but the favorable balance of 1938 operations of approximately $14,000 resulted in a net increase in surplus of about $8500.

The auditors' report includes a comparison of the financial condition of the Society at the close of each of the past five years. The surplus in the general funds account, exclusive of special and designated funds, is $58,619.60, which compares with $50,029.53 a year ago and with $43,624.44 two years ago.

It will be noted that the principal of the A.S.T.M. Research Fund was approximately doubled during 1937, the total at the close of the year being $21,313.26. This came about through the gift of 98 shares of General Motors common stock made by Past-President Frank O. Clements, previously announced, and contributions from the Society entrance fees—$1680 representing half of the current entrance fees and $2500 from entrance fees from earlier years as noted above.

No account has been taken in the accompanying financial statement of the assets of the Society in the form of publications in stock, with the exception of the cost value, $1210.40, of the copies still in stock of the Joint A.S.M.E.—A.S.T.M. Symposium on Effect of Temperature on the Properties of Metals purchased by the Society from a joint account, described in a previous report;[1] this amount is included in the statement of assets. An inventory of technical publications on June 1, 1938, may be summarized as follows:

	NUMBER OF COPIES
Year Book	390
Proceedings	4 498
Index to Proceedings, 5 parts. total	1 667
1936 Book of A.S.T.M. Standards:	
Part I, Metals	994
Part II, Non-Metals	1 262
1937 Supplement to Book of Standards	1 525
1937 Book of A.S.T.M. Tentative Standards	388
Methods of Chemical Analyses of Metals	414
Index to Standards and Tentative Standards	2 100
Selected Standards for Students in Engineering	2 380
Reprints of Standards and Tentative Standards (approximate)	50 000
Symposium on Effect of Temperature on the Properties of Metals	320
Special Reprints (approximate)	27 500

1938 Finances.—Society operations for 1938 are based upon budgeted operating receipts of $148,150, of which $139,150 is estimated current receipts and $9000 is applied to 1938 operations from the budget surplus of 1937. Receipts from dues and entrance fees are estimated at $83,500, receipts from sales of publications at $43,750, and miscellaneous receipts at $11,900. Disbursements have been estimated at $146,700, leaving $1450 for contingencies. The budget of disbursements provides fully for all of the Society's normal operating expenses,

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 53 (1932).

REPORT OF THE AUDITORS FOR THE FISCAL YEAR, JANUARY 1, 1937, TO DECEMBER 31, 1937

PHILADELPHIA, January 11, 1938

MR. C. L. WARWICK, *Secretary-Treasurer*
AMERICAN SOCIETY FOR TESTING MATERIALS
Philadelphia, Pa.

Dear Sir:

We have examined the books and accounts of your Society for the year ended December 31, 1937. The books and accounts were found correct and in satisfactory condition.

We have prepared the annexed Balance Sheet as of December 31, 1937, and Statement of Cash Receipts and Disbursements for the twelve months ended that date, together with other supporting schedules, all of which are in agreement with the records of your Society.

Investments owned were verified by actual inspection and count and found to be in agreement with the records of the Society. All income from investments was properly accounted for. In this connection the income from 98 shares of General Motors Stock is not included under the income of the Society in any of the schedules herewith as same is payable to an annuitant as and when received under agreement dated February 20, 1937.

Respectfully submitted,

(Signed) JOHN HEINS AND CO.

BALANCE SHEET AS OF DECEMBER 31, 1937
(Including Special and Designated Funds)

ASSETS

General Funds:				
Current: Cash	$36 086.08			
Less checks drawn as of December 31, 1937—Cost of *Proceedings* in hands of Secretary-Treasurer that date.	15 400.00			
		$20 686.08		
Investments (Market Value, $28 156.25)—Cost		37 599.49		
Accounts Receivable		9 296.38		
Total Current Assets—General Fund			$67 581.95	
Furniture and Fixtures			7 029.87	
A.S.T.M.-A.S.M.E. Symposium on Effect of Temperature: Special Account for Financing Book			1 210.40	
Total General Funds				$75 822.22
Special and Designated Funds:				
Cash: A.S.T.M. Research Fund		$2 931.68		
Dudley Medal and Marburg Lecture Fund.		627.92		
Committee Funds		6 293.96		
			$9 853.56	
Investments:				
A.S.T.M. Research Fund (Market Value, $12 624.38)—Cost or book value		$19 633.26		
Dudley Medal and Marburg Lecture Fund (Market Value, $2 513.75)—Cost		6 625.00		
Committee Funds (Market Value, $6 208.12) Cost		6 000.00		
			32 258.26	
Total Special and Designated Funds				42 111.82
Total Assets				$117 934.04

Total Assets (brought forward)			$117 934.04

LIABILITIES

General Funds:			
Current: Accounts Payable—			
Committee A-1	$28.66		
Committee C-1	59.97		
Advance Collections	2 052.23		
Total Current Liabilities—General Fund		$2 140.86	
Life Membership Fund	$3 005.20		
Headquarters Fund	3 041.56		
Publication Fund	3 015.00		
Book of Standards Reserve	6 000.00		
Surplus	58 619.60		
		73 681.36	
Total General Funds			$75 822.22
Special and Designated Funds:			
A.S.T.M. Research Fund		$22 564.94	
Dudley Medal and Marburg Lecture Fund		7 252.92	
Committee Funds		12 293.96	
Total Special and Designated Funds			42 111.82
Total Liabilities and Funds			$117 934.04

COMPARISON OF GENERAL FUNDS FOR FISCAL YEARS 1933–1937, INCLUSIVE

At Close of Fiscal Year	Assets				Liabilities			
	Cash	Investments[a]	Accounts Receivable and Miscellaneous	Furniture and Fixtures	Accounts Payable and Miscellaneous	Reserve for Book of Standards	Miscellaneous Funds[a]	Surplus
1933	$7 869.45	38 266.50	16 739.78	6 092.51	3 178.98	....	19 008.68	46 780.58
1934	3 792.12	38 924.05	9 767.35	8 010.84	2 204.99	5 023.44	7 061.76	46 204.17
1935	10 514.73	36 180.42	9 220.39	7 489.70	2 695.60	10 023.44	7 061.76	43 624.44
1936	6 943.82	29 767.23	16 088.91	6 915.95	2 624.62	....	7 061.76	50 029.53
1937	20 686.08	37 599.49	10 506.78	7 029.87	2 140.86	6 000.00	9 061.76	58 619.60

[a] The funds reported in this column for 1933 include the principal of the A.S.T.M. Research Fund, which beginning with 1934 is no longer included under "General Funds."

RECEIPTS AND DISBURSEMENTS

FOR THE PERIOD JANUARY 1, 1937, TO DECEMBER 31, 1937

Cash balance, January 1, 1937			$6 943.82

RECEIPTS

Operating Receipts (Budgeted):			
Dues and Entrance Fees:			
Current Dues	$74 170.53		
Past Dues	766.64		
Advance Dues	1 465.00		
Income, Life Membership Fund	150.00		
Entrance Fees	3 372.50		
Total Dues		$79 924.67	
Sale of Publications:			
Separate Standards	$6 871.45		
Book of Standards	19 174.49		
Book of Standards (Members, both parts)	481.88		
Book of Tentative Standards	10 384.93		
Methods of Chemical Analyses of Metals	1 837.81		
Proceedings	4 048.45		
Collective Index to Proceedings	547.10		
Selected Standards for Students	793.75		
Bulletin Subscriptions (Non-Members)	115.90		
Special Reprints and Miscellaneous	22 512.09		
Total Sale of Publications		66 767.85	
Miscellaneous:			
Binding (Members)	$239.00		
Advertising, Bulletin	7 125.20		
Advertising, Index	1 550.50		
Interest on Deposits and Investments	2 598.13		
Registration and Other Fees, Annual Meeting	2 059.41		
A.S.T.M. Exhibit, Annual Meeting	5 315.00		
Committee A-1 for Technical Assistant	700.00		
Miscellaneous	232.85		
Total Miscellaneous Items		19 820.09	
Total Operating Receipts (Budgeted)		$166 512.61	
Non-Operating Receipts (Not Budgeted):			
Investments, Matured or Sold	$12 564.80		
Excess Remittances	184.15		
Accrued Interest	159.09		
International Association for Testing Materials, Dues and Publications	728.14		
Symposium on Effect of Temperature	206.45		
Committee C-1 for Technical Assistant	1 500.00		
Total Non-Operating Receipts		15 342.63	
Total Receipts			181 855.24
Carried forward			$188 799.06

Brought forward			$188 799.06

DISBURSEMENTS

Operating Disbursements (Budgeted):			
Publications:			
Year Book	$1 816.42		
Book of Standards Supplement	2 873.91		
Book of Tentative Standards	4 679.00		
Methods of Chemical Analyses of Metals	718.27		
Selected Standards for Students	824.20		
Proceedings	19 270.97[a]		
Preprints	3 132.36		
Regional Meeting Papers	1 426.64		
Bulletin and Circulars to Members	7 530.91		
Separate Standards	3 387.26		
Index to Standards and Tentative Standards	1 709.80		
Collective Index to Proceedings	1 146.80		
Reprints (Reports, Papers, Symposiums, etc.)	13 711.48		
Miscellaneous Printing (Authors' Reprints, etc.)	690.81		
Total Disbursements, Publications		$62 918.83	
Salaries		52 264.50	
General Office Expenses		12 612.53	
Expenses, Standing and District Committees		3 711.75	
Expenses, Meetings and A.S.T.M. Exhibit		4 739.51	
Traveling Expenses, Administrative and Special Committees		2 106.98	
American Standards Assn. and Sectional Committees		1 000.00	
Rent, Headquarters		4 200.00	
Furniture and Fixtures		1 118.19	
Principal, A.S.T.M. Research Fund (one-half current year's entrance fees)		1 680.00	
Miscellaneous		175.51	
Total Operating Disbursements (Budgeted)		$146 527.80	
Non-Operating Disbursements (Not Budgeted):			
Investments	$15 517.50		
Accrued Interest	159.09		
Refund of Excess Remittances	184.15		
International Assn. for Testing Materials	738.14		
Symposium on Effect of Temperature	15.00		
Technical Assistant, Committee C-1	1 471.30		
Principal, A.S.T.M. Research Fund	2 500.00		
Final Contribution to Deficit I. A. T. M.	1 000.00		
Total Non-Operating Disbursements		21 585.18	
Total Disbursements			$168 112.98
Cash Balance, December 31, 1937			$20 686.08

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[a] This amount includes $15,400.00 in the form of checks drawn against cost of *Proceedings*, but not actually paid on December 31, 1937, pending final completion of the publication work.

In addition to the general funds of the Society, the Secretary-Treasurer has on hand the following funds:

A.S.T.M. RESEARCH FUND

Principal Account:	*Total*	*Invested*	*Uninvested Cash*
Balance, January 1, 1937, as Reported	$10 539.21	$10 082.91	$456.30
Receipts—Net Proceeds from Sale of Securities	+83.20	−858.90	+942.10
Reimbursement from Income for Over-invested Principal	+6.10		+6.10
Contribution A.S.T.M. Entrance Fees	+4 180.00		+4 180.00
Gift—98 Shares General Motors Common Stock[a]	+6 504.75	+6 504.75	
	21 313.26	15 728.76	5 584.50
Disbursements—Purchase of Securities		+3 904.50	−3 904.50
Balance, December 31, 1937	$21 313.26	$19 633.26	$1 680.00

Income Account:			
Cash Balance, January 1, 1937	$1 112.19		
Receipts			
Interest on Deposits and Investments	622.11	$1 734.30	
Disbursements			
Research Project on Capping of Hollow Tile (Committee C-15)	$100.00		
Research Project on Fatigue Tests of Cast Iron (Committee A-3)	200.00		
Computation and drafting work in revising A.S.T.M. Viscosity-Temperature Charts (Committee D-2)	155.00		
Expenses, account British Cooperative Corrosion Tests	27.62	$482.62	
Cash Balance, December 31, 1937			$1 251.68

DUDLEY MEDAL AND MARBURG LECTURE FUND

Balance, January 1, 1937:			
Principal—Investments (At Cost)	$6 625.00		
Income—Cash	571.17	$7 196.17	
Receipts			
Interest on Investments	330.00	$7 526.17	
Disbursements			
Honorarium, 1937 Lecturer	$200.00		
Cost of 1937 Medal	70.00		
Engrossing 1937 Lecture Certificate	3.25	273.25	
Balance, December 31, 1937:			
Principal—Investments (At Cost)		$6 625.00	
Income—Cash		627.92	$7 252.92

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[a] The income from these shares is by agreement paid to an annuitant.

COMMITTEE FUNDS

Committee A-1 on Steel	$517.04	
Committee A-5 on Corrosion of Iron and Steel	3 406.64	
Committee A-5, Subcommittee X on Embrittlement Investigation	133.59	
Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys	3 322.91	
Committee B-6 on Die-Cast Metals and Alloys	207.44	
Committee C-1 on Cement	979.85	
Committee C-1, Cement Reference Laboratory	398.55	
Committee C-1 on Cement, Studies of Additions to Cement	463.95	
Committee C-9 on Concrete and Concrete Aggregates	662.72	
Committee C-15 on Manufactured Masonry Units	296.56	
Committee C-18 on Natural Building Stones and Slate	163.76	
Committee D-1 on Paint, Varnish, Lacquer, and Related Products	36.09	
Committee D-13 on Textile Materials	69.75	
A.S.A. Sectional Committee on Specifications for Cast-Iron Pipe and Special Castings	491.54	
A.S.A. Sectional Committee on Classification of Coals	1 128.65	
Miscellaneous	14.92	
Total Committee Funds		$12 293.96
Accounted for as follows:		
Investments (At Cost)	$6 000.00	
Cash Balance, December 31, 1937	6 293.96	
		$12 293.96

INVESTMENTS, DECEMBER 31, 1937

Par Value:	GENERAL FUNDS	*Book Value*	*Market Value*[1]
$9 000	Baltimore & Ohio R. R. Refunding and General Mortgage Bonds, Series F, 5's, due 1996	$9 106.55	$3 431.25
4 000	New York, Chicago & St. Louis R. R. Refunding Mortgage Bonds, Series C, 4½'s, due 1978	2 805.61	2 470.00
3 000	Wheeling Steel Corp., First Mortgage Sinking Fund Bonds, Series A, 4½'s, due 1966	3 045.00	2 580.00
3 000	Republic Steel Corp., General Mortgage Bonds, Series B, 4½'s, due 1961	3 000.00	2 340.00
2 000	North Station Industrial Bldg., Inc., First Mortgage Sinking Fund Bonds, 5's, due 1962	1 850.00	1 300.00
500	Saguenay Power Co., Ltd., First Mortgage Sinking Fund Bonds, Series A, 4¼'s, due 1966	500.00	500.00
3 000	Armour and Co., First Mortgage, 20-yr. Sinking Fund Bonds, Series C, 4's, due 1957	2 955.00	2 595.00
3 000	Oklahoma Natural Gas, First Mortgage Bonds, Series A, 4½'s, due 1951	2 962.50	2 932.50
3 000	Pennsylvania State Water Corp., First Collateral Trust Bonds, 4¼'s, due 1966	2 850.00	2 610.00
4 000	Montana Power Co., First and Refunding Mortgage Bonds, 3¾'s, due 1966	3 780.00	3 600.00
	50 shares Great Northern Ry. $6.00 Preferred Stock, par value $100	1 774.83	1 075.00
	30 shares Northern States Power Co., $5 Preferred Stock, no par value	2 970.00	2 722.50
		$37 599.49	$28 156.25

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[1] Market Values, except on First Mortgage Real Estate 1315–1317 Spruce Street, 6's, 1945, on which there was no available quotation, have been taken from the Bank and Quotation Record as of December 31, 1937.

INVESTMENTS—*Continued*

A.S.T.M. RESEARCH FUND

Par Value:		*Book Value*	*Market Value*[1]
$1 500	Baltimore & Ohio R. R. Refunding and General Mortgage Bonds, Series F, 5's, due 1996	$1 511.25	$571.88
2 000	New York, Chicago & St. Louis Refunding Mortgage Bonds, Series C, 4½'s, due 1978	1 400.26	1 235.00
2 000	First Mortgage Real Estate Bonds, 1315–1317 Spruce St., Philadelphia, 6's, due 1945	2 000.00	1 200.00
3 000	North Station Industrial Bldg., Inc., First Mortgage Sinking Fund Bonds, 5's, due 1962	2 812.50	1 950.00
1 500	Saguenay Power Co., Ltd., First Mortgage Sinking Fund Bonds, Series A, 4¼'s, due 1966	1 500.00	1 500.00
	29 shares Consumers Power Co., $4.50 Preferred Stock, no par value	2 914.50	2 320.00
	10 shares Northern States Power Co., $5 Preferred Stock, no par value	990.00	907.50
	98 shares General Motors Corp., Common Stock, par $10[a]	6 504.75	2 940.00
		$19 633.26	$12 624.38

DUDLEY MEDAL AND MARBURG LECTURE FUND

$500	Baltimore & Ohio R. R. Refunding and General Mortgage Bonds, Series C, 6's, due 1995	$550.00	$218.75
6 000	Baltimore & Ohio R. R. Refunding and General Mortgage Bonds, Series A, 5's, due 1995	6 075.00	2 295.00
		$6 625.00	$2 513.75

COMMITTEE FUNDS

$5 000	U. S. Treasury Bonds, 2¾'s, due 1947	$5 000.00	$5 189.06
1 000	U. S. Treasury Bonds, 2⅞'s, due 1960	1 000.00	1 019.06
		$6 000.00	$6 208.12
	Total, All Funds	$69 333.34	$49 502.50

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[1] Market Values, except on First Mortgage Real Estate 1315–1317 Spruce Street, 6's, 1945, on which there was no available quotation, have been taken from the Bank and Quotation Record as of December 31, 1937.

[a] The income from these shares is by agreement paid to an annuitant.

including all regular and special publications and the enlarged *Bulletin*.

The Executive Committee reviews the budget of receipts and disbursements quarterly and makes any adjustments of appropriations for operating expenses that may be needed in the light of actual receipts.

Since the beginning of the present fiscal year the Executive Committee has decided in view of the general financial and economic conditions to invest a portion of the Society's surplus in common stocks, and in January approximately $10,000 was invested in common stock of five corporations, namely, American Radiator and Standard Sanitary Corp., E. I. du Pont de Nemours and Co., Inc., General Electric Co., Standard Oil Co. of New Jersey, and Union Carbide and Carbon Corp. Also, uninvested principal in the A.S.T.M. Research Fund at the close of the last fiscal year has been invested in a first sinking fund bond of Baldwin Locomotive Works and a convertible debenture bond of the Allis-Chalmers Mfg. Co. These investments, of course, do not appear in the present auditors' report. They bring the total book value of Society investments to about $82,000, of which approximately 70 per cent is invested in bonds, 10 per cent in preferred stocks and 20 per cent in common stocks.

The Commissioner of Internal Revenue has ruled that the provisions of the Social Security Act respecting taxes for unemployment compensation and old-age retirement do not apply to the Society and its employees.

Retirement Plan for Employees:

The Executive Committee, with the cooperation of the employees of the Society, has set up a Retirement Plan for Employees, which provides a retirement income effective at age 65 for men and age 60 for women (or upon earlier or later retirement at the discretion of the Society) with a death benefit equal to or in excess of total deposits. The Society contributes a minimum of $2 per month, with increased amounts for employees having over ten years' service at the rate of 20 cents per month for each year of service at the institution of the Plan; the Society's contribution is matched by the employee. The combined monthly payments constitute the premiums for individual Deferred Income Policies in the Penn Mutual Life Insurance Co. of Philadelphia, which are jointly in the control of the Society and the individual employee. The Plan includes a life insurance feature for those who elect it, at slightly increased premiums, divided equally between the Society and the employee. The guaranteed values of the policies at the maturity ages specified above range from approximately $1900 to $3300, depending upon age and length of service; these values are increased if dividends are allowed to accumulate, as is intended. The retirement incomes resulting are of course comparatively small, but the annual expense to the Society, approximately $700, is as much as the Executive Committee believes it can appropriate for this purpose at present. (This is slightly over 1¼ per cent of the present annual salary schedule.)

Employees are eligible to participate in the Retirement Plan after one year's service. Of the present twenty employees, sixteen were eligible when the Plan was formally instituted on May 3, 1938, and all have participated.

An agreement between the Society and its employees covers a number of matters that may arise in the life of the various policies. Principal among these is the provision that if an employee leaves the employ of the Society other than through retirement, the employee and the Society are each entitled to their respective shares of the then cash equity. The Society will place all cash equities thus returned to it in a Retirement Fund Reserve.

Headquarters:

The office space comprising the Society headquarters was increased at the beginning of the year by leasing a room adjacent to the headquarters, having an area of approximately 550 sq. ft., bringing the total floor area of Society headquarters to approximately 4000 sq. ft. This increased space was needed because additions to the staff in the past three years had caused crowded conditions in certain portions of the office. The Assistant Treasurer and his staff have occupied the new room, and other rearrangements have made available a new small conference room. Working conditions throughout the offices have been improved and there is now room for substantial expansion without crowding.

Cooperative Activities:

The Society's contacts with the American Standards Association constitute one of its most important cooperative activities. During the past year the principal work has been more or less routine in nature, involving the submission of new and revised standards to the

A.S.A. for approval as American Standard. The annual report of Committee E-10 on Standards presents this work in detail.

F. M. Farmer was reappointed as one of the Society's representatives on the Standards Council of A.S.A. for the term of three years ending December 31, 1940. Mr. Farmer is at present chairman of the Council. The death of J. A. Capp left a vacancy in the Society's representation on the Standards Council, which has been filled by the appointment of Vice-President H. H. Morgan for the remainder of the term, ending December 31, 1939. The Assistant Secretary of the Society has been reappointed as alternate for a term of one year.

The Executive Committee wishes here to pay sincere tribute to Mr. Capp in recognition of the outstanding service he gave to the cause of standardization represented by the work of the American Standards Association. He had served continuously since 1918 as the Society's representative in that organization and his untiring efforts in the field of standardization will stand as one of his most enduring monuments.

Upon invitation from the Board of Directors of the American Standards Association to nominate a director to serve on the Board, the Executive Committee nominated Past-President G. W. Thompson. In April, 1938, he was formally elected a member of the Board and will serve for a term of three years.

Vice-President T. G. Delbridge was appointed as the Society's representative on the Sectional Committee on Valid Certification. Rudolph P. Miller was reappointed as the Society's representative on the Building Code Correlating Committee. F. C. Welch was named as A.S.T.M. representative on Sectional Committee A-42 on Specifications for Plastering, succeeding J. A. Murray, resigned.

The Society of Automotive Engineers, through its Iron and Steel Division, deals with many specifications and tests of interest to committees of A.S.T.M. In order to provide closer contacts and to make the work of the Society more readily available to S.A.E., the Executive Committee appointed as A.S.T.M. representative on the Iron and Steel Division, P. J. Smith, a member of the staff, whose work keeps him closely in touch with the standardization activities of our committees.

The American Documentation Institute is a non-profit corporation organized in 1937 for the promotion and development of documentation in scholarly and scientific fields. Its members are nominated by the various organizations in these fields, and upon invitation of the Institute the Society has named Stanton Walker as a member. Developments in documentation are of particular interest to Committee E-6 on Papers and Publications, of which Mr. Walker is a member.

The special committee formed a year ago to study the relationship of the Society to laboratory service performed by the large variety of laboratories using A.S.T.M. test methods and specifications has been engaged during the year in this study, which however has not reached the stage that justifies a report.

International Relations:

International Association for Testing Materials.—At the London Congress of the International Association for Testing Materials, held in April, 1937, the basis of membership in the Association was changed from personal and company membership to membership of the national associations for testing materials or their equivalent in the associated countries. Revised Statutes were adopted at the Congress as follows:

I.A.T.M. STATUTES

Art. 1.—Name of the Association:
"The International Association for Testing Materials."—I.A.T.M.

Art. 2.—Objects of the Association:
Securing international cooperation, exchange of views, experience and knowledge in regard to all matters connected with the testing of materials and contributing toward the solution of relevant problems. The principal means of securing these results is to be the holding of periodical international congresses at intervals of not less than three or more than five years, preferably at three-year intervals. The formulation of standards is outside the scope of the Association but giving technical advice regarding standardization to approved standardizing bodies is within its scope.

Art. 3.—Membership of the Association shall be open to the National Associations for Testing Materials or equivalent organizations in the associated countries.

Art. 4.—The Association shall be governed by a Permanent Committee consisting of one member from each National Association adhering to the Association. Each member of the Permanent Committee shall be elected by his National Association or in the absence of a National Association, by the equivalent organization in that country.

Art. 5.—The Permanent Committee shall at each meeting invite the representative of the country in which the meeting is held to act as chairman of the meeting.

Art. 6.—The Permanent Committee shall appoint an Honorary Secretary, if possible the member representing the country where the next Congress is to be held; alternatively, he may be an additional delegate to the Committee nominated by that country. The Honorary Secretary shall carry on the business of the Association at and between the meetings of the Permanent Committee.

Art. 7.—The Permanent Committee shall hold at least one meeting in every year; these meetings shall be convened by the Honorary Secretary who shall be also empowered to call such additional meetings as appear necessary; extra meetings shall also be called at the request of representatives of not less than four countries. The Permanent Committee shall also meet at the time of each Congress.

Art. 8.—At the meeting of the Permanent Committee held at the time of each Congress, the country and the year in which the next Congress shall take place shall be designated and general decisions taken regarding the scope and program of that Congress. The National Association or equivalent organization of the country designated to hold the next Congress shall take over entirely the responsibility for the arrangement, organization and finance of that Congress, in addition to the publication of the Congress Book.

Art. 9.—The languages of all associated countries are to be regarded as official languages at Congresses.

There are no annual dues. The Association continues to be governed by a Permanent Committee consisting of one member appointed by each national association adhering to I.A.T.M. The business of the Association at and between meetings of the Permanent Committee is carried on by an Honorary Secretary appointed by the Permanent Committee from the country where the next Congress is to be held. Entire responsibility for the arrangement, organization and financing of the Congress, including publication of the Congress Book, is assumed by the national association of the country in which the Congress is held.

At its meeting last January, the Executive Committee took action whereby the Society adheres to the I.A.T.M. as the American national society for testing materials and appointed the Secretary-Treasurer as the American member of the Permanent Committee. Since meetings of that committee are held in Europe it was considered desirable to appoint an alternate. Accordingly, W. L. Cooper, Director of Foreign Operations, Robert W. Hunt Co., London, has accepted appointment as alternate.

It is planned to hold the next International Congress in Germany in 1940 under the auspices of the Deutscher Verband für die Materialprüfungen der Technik. Dr.-Ing. P. Goerens is President of the Association to serve until the end of the next congress. Dr. M. Moser of Berlin is Honorary Secretary.

British Joint Committee on Materials.—During the year there was formed in Great Britain the British Joint Committee on Materials and Their Testing, comprising representatives of over twenty engineering and industrial institutions, for the purpose of coordinating British activities in the study of materials and their testing and of supplementing the materials testing activities of the cooperating organizations. The Joint Committee now represents the interests of Great Britain in the International Association for Testing Materials. The Executive Committee has extended the Society's felicitations and best wishes to this new organization and its assurance of the desire to cooperate in all matters of mutual interest.

The British Committee recently invited the Society to sponsor an American contribution to a Discussion on Non-Destructive Methods of Testing, to be held in London on November 25 next under the ægis of the Institution of Electrical Engineers. This invitation has been accepted and three members of the Society, Messrs. N. L. Mochel, H. H. Lester and R. L. Sanford, are collaborating in the preparation of the paper.

Arrangements have been made with the British Standards Institution for an exchange of preprints of standards of B.S.I. and A.S.T.M. in order to facilitate study by the committees of the two organizations of proposed standards while in the formative stages.

The Society was represented at the Rubber Technology Conference in London in May, 1938, by R. P. Dinsmore, Goodyear Tire and Rubber Co.

Various appointments to administrative committees of the Society, to joint committees and committees of other organizations have been made by the Executive Committee and reported currently in the Society *Bulletin*.

Respectfully submitted on behalf of the Executive Committee,

A. E. WHITE,
President.

C. L. WARWICK,
Secretary-Treasurer.

June, 1938.

REPORT OF COMMITTEE A-1
ON
STEEL

As a result of two series of meetings, the first in New York City, June 28 and 29, 1937, the second in Rochester, N. Y., March 7 to 9, 1938, Committee A-1 on Steel is able to report considerable progress in the advancement of its standardization program. All of the meetings were well attended by members, and many visitors were present at the various sessions, indicating a pronounced interest in the committee's work. The report also indicates considerable activity in the development of specification requirements for various steel products which are not covered by existing specifications. Several subcommittee and section meetings have been held during the year as the need required.

Since the 1937 annual meeting, 13 new members have been elected and 9 resignations accepted, the committee membership now totaling 211, of whom 98 are classified as producers, 89 as consumers, and 24 as general interest members.

All of the subcommittees have held elections for chairmen with the result that C. T. Edgerton, Crucible Steel Co. of America, has been chosen as the new chairman of Subcommittee IV on Spring Steel and Steel Springs, H. P. Bigler, Rail Steel Bar Association, chairman of Subcommittee V on Steel Reinforcement Bars, and E. F. Lundeen, The American Rolling Mill Co., chairman of Subcommittee XIX on Sheet Steel and Steel Sheets; and all other subcommittee officers have been reelected for the ensuing term of two years.

Losses by Death.—During the year Committee A-1 has lost by death several members, including H. C. Myers, R. W. Johnson, A. N. Lukens, G. D. Boyd, and J. A. Capp. The committee records its appreciation of their generous services. Of these men, one had been a member for 27 years, was vice-chairman for several years and served as chairman; in addition, he had been active on numerous subcommittees. The committee wishes to pay tribute to him and has adopted the following resolution:

Resolution on the Death of John A. Capp
1870 – 1938

In the death on January 5, 1938, of John A. Capp, Materials Engineer, General Electric Co., Committee A-1 on Steel loses a member who did yeoman service in its behalf, one who had an amazing grasp of technical details, an extremely broad knowledge of engineering materials and their testing, and above all, a keen appreciation of the viewpoint of producer and consumer alike.

A member of Committee A-1 for 27 years, vice-chairman 1914 to 1917, he was honored by election as chairman in 1918. For years he rendered invaluable service to numerous subcommittees and the Advisory Committee. Especially was his unique precision of expression an asset which enabled him to clarify many a situation.

Of far greater influence in the progress of the committee's work was his knowledge of "human engineering"—dealing with others in a human way. It was his conviction that nowhere did the spirit of "give and take" become of more paramount significance than in A.S.T.M. committee work—and that with that right spirit a member could accomplish not what he wanted, but what he ought to have.

Of those two outstanding Committee A-1 members, Stevenson and Capp, who better than others were able to direct into valuable channels the influential joint efforts of the producer and consumer, neither now remains to carry on. Yet their powers of influence were such as to leave indelibly imprinted in the minds and hearts of those associated with them some of those intangibles which are essential in reconciling diverging points of view.

Housed in a rugged frame, and with a sometimes gruff exposition, Capp the engineer was never paramount to Capp the man and friend.

Fitting that he should have been honored as an officer of this committee; fittingly selected to high position in the Society and Honorary Membership; but more fitting by far that his memory should linger, as it surely will, as a worthy friend—sometimes opposer, but always Capp the understanding.

In meeting assembled, Committee A-1 on Steel pays homage to him for the principles he maintained, and it records appreciation for services beyond number.

Tentative Standards and Revisions Approved During the Past Year.—Subsequent to the 1937 annual meeting, Committee A-1 on Steel presented to the Society on August 26, 1937, through Committee E-10 on Standards the recommendations listed below, all of which were accepted:[1]

Tentative Specifications for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 - 37 T),

Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 - 37 T), which together with the above specifications are a revision of and supersede the Standard Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 - 36), which were by simultaneous action withdrawn,

Revision of Tentative Specifications for Alloy-Steel Bolting Materials for High-Temperature Service from 750 to 1100 F., Metal Temperatures (A 193 - 37 T), and

Tentative Revision of Standard Specifications for Boiler and Firebox Steel for Locomotives (A 30 - 33).

The three tentative specifications and the tentative revision appear in the 1937 *Proceedings*.[2]

Because of the widespread use of the grade of pipe covered in Tentative Specifications A 206 - 37 T, especially by the power industries, the committee considered it desirable to withdraw the composition from the then existing Standard A 158 - 36 and cover it in new tentative specifications, embodying at the same time certain desirable changes. When Specifications A 158 were adopted as standard, it was expected that changes would be proposed periodically to keep several types of alloy steels in line with current trends. It seemed best to revert the standard to tentative and to revise it, making certain deletions including the carbon-molybdenum grade covered in the new specifications, and incorporating five new classes of alloy steel.

The changes in Specifications A 193, involving the transfer from an appendix to the body of the specifications, of chemical and physical properties of various grades of steel, were urged by large users of the material.

The revision of Standard Specifications A 30 involved the inclusion of an additional grade of firebox steel. This change was desirable to bring the specifications in line with those of the Association of American Railroads.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee A-1 reported the following results of the letter ballot vote of a total of 123 ballots returned from a committee membership of 215: A 206 - 37 T, affirmative 71, negative 0, ballots marked "not voting" 52; A 158 - 37 T, affirmative 70, negative 1, ballots marked "not voting" 52; A 193 - 37 T, affirmative 74, negative 0, ballots marked "not voting" 49; A 30 - 33, affirmative 65, negative 0, ballots marked "not voting" 58.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 633, 622, 616, 1303 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 151, 140, 129, 1561.

Recommendations Affecting Standards[1]

For convenience, the recommendations of the committee affecting its standard and tentative specifications are listed below in summarized form with an analysis of the letter ballot given in Table I. Certain of these recommendations are referred to further in the discussion of subcommittee activities.

New Tentative Standard:

The committee recommends that the new Tentative Specifications for Normalized Quenched-and-Tempered Alloy-Steel Forgings be accepted for publication as tentative, as appended hereto.[2] These are in effect a tentative revision of and will supersede, when adopted, the present Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts and Other Forgings for Locomotives and Cars (A 63 – 36).

Revisions of Tentative Standards:

The committee recommends that the following tentative specifications be revised, as indicated in the Appendix, and continued as tentative:

Tentative Specifications for:

Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 37 T),
Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T), and
Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A 194 – 36 T).

Tentative Revisions of Standards:

The committee recommends that revisions, as appended hereto,[3] of the five standard specifications listed below be published as tentative for one year before they are referred to letter ballot of the Society for adoption as standard:

Standard Specifications for:

Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 – 36),
Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 36),
Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 36),
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F. (A 182 – 36), and
Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33).

Adoption of Tentative Standards as Standard:

The committee recommends that the following seven tentative specifications be approved for reference to letter ballot of the Society for adoption as standard:

Tentative Specifications for:

Structural Nickel Steel (A 8 – 36 T),[4]
Seamless Cold-Drawn Alloy-Steel (4 to 6 per cent Chromium) Heat-Exchanger and Condenser Tubes (A 187 – 36 T),[4]
Seamless Alloy-Steel (4 to 6 per cent Chromium) Still Tubes for Refinery Service (A 188 - 36 T),[4]
Carbon-Silicon-Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (A 201 – 37 T),[5]
Chrome-Manganese-Silicon (CMS) Alloy-Steel Plates for Boilers and Other Pressure Vessels (A 202 – 37 T),[5]
Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204 – 37 T),[5] with editorial change as shown in the Appendix, and
Cold-Rolled Strip Steel (A 109 – 35 T).[6]

Adoption as Standard of Tentative Revisions of Standards:

The committee recommends that the revisions which were published as tentative last year[7] in the following standards be approved for reference to letter ballot of the Society for adoption as standard:

Revisions of Standard Specifications for:

Structural Rivet Steel (A 141 – 36),
High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and

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[1] See Editorial Note, p. 66.

[2] See p. 586.

[3] See pp. 1310 to 1313.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, pp. 561, 612, 619 (1936); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1, 99, 113.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 565, 572, 582 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 11, 18, 28.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 544 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 35.

[7] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1303 to 1305 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1561 to 1563.

Under in Thickness) (A 149 – 36), with editorial change as shown in the Appendix,

High Tensile Strength Carbon-Steel Plates for Fusion - Welded Pressure Vessels (Plates over 2 in. to 4 in., Inclusive, in Thickness) (A 150 – 36), with editorial change as shown in the Appendix, and

Boiler and Firebox Steel for Locomotives (A 30 – 33).

The committee asks for the necessary nine-tenths vote at the annual meeting.

The recommendations appearing in this report have been referred to letter ballot of the committee, which consists of 211 members, with the results shown in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Specifications for Normalized Quenched-and-Tempered Alloy-Steel Forgings	86	5	56
II. REVISIONS OF TENTATIVE STANDARDS			
Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 37 T)	82	0	65
Specifications for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T)	76	1	70
Specifications for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A 194 – 36 T)	81	0	66
III. TENTATIVE REVISIONS OF STANDARDS			
Specifications for Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 – 36)	82	0	65
Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 36)	81	1	65
Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 36)	84	1	62
Specifications for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F. (A 182 – 36)	82	1	64
Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33)	79	2	66
IV. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Structural Nickel Steel (A 8 – 36 T)	90	0	57
Specifications for Seamless Cold-Drawn Alloy-Steel (4 to 6 per cent Chromium) Heat-Exchanger and Condenser Tubes (A 187 – 36 T)	71	1	75
Specifications for Seamless Alloy-Steel (4 to 6 per cent Chromium) Still Tubes for Refinery Service (A 188 – 36 T)	71	1	75
Specifications for Carbon-Silicon-Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (A 201 – 37 T)	84	1	62
Specifications for Chrome-Manganese-Silicon (CMS) Alloy-Steel Plates for Boilers and Other Pressure Vessels (A 202 – 37 T)	72	1	74
Specifications for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204 – 37 T), with editorial change	73	0	74
Specifications for Cold-Rolled Strip Steel (A 109 – 35 T)	78	0	69
V. ADOPTION AS STANDARD OF TENTATIVE REVISIONS OF STANDARDS			
Specifications for Structural Rivet Steel (A 141 – 36)	89	0	58
Specifications for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 – 36), with editorial change	83	2	62
Specifications for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates over 2 in. to 4 in., Inclusive in Thickness) (A 150 – 36), with editorial change	86	2	59
Specifications for Boiler and Firebox Steel for Locomotives (A 30 – 33)	73	0	74

ACTIVITIES OF SUBCOMMITTEES

Certain features of the committee's work are discussed below, grouped in the order of the respective subcommittees responsible.

Subcommittee II on Structural Steel for Bridges, Buildings and Rolling Stock (F. H. Frankland, chairman).—No major criticism having been received of the Tentative Specifications for Structural Nickel Steel (A 8 – 36 T), which replaced the former standard and provided for nickel steel of higher strength; their adoption as standard is proposed. Subcommittee II is continuing its consideration of the status of specifications for steel sheet piling. It is studying, through a special section, a request to formulate requirements for structural bolts, and its section on high-strength rivet specifications is continuing work in this field. At present, the results of a series of tests are being awaited. Requirements for manganese-vanadium-steel structural shapes and bars, and rivet bars are being studied.

Subcommittee VI on Steel Forgings and Billets (W. M. Barr, chairman).—The proposed Tentative Specifications for Normalized Quenched-and-Tempered Alloy-Steel Forgings, appended hereto,[1] offered as a revision of the existing Standard Specifications A 63 – 36 and which will eventually supersede the standard, contain new requirements more in line with consumer requirements and take cognizance of improvements in manufacturing operations. The subcommittee is continuing its study of various forging specifications in its charge. Its section studying carbon-steel forging specifications is developing a plan to use numeric designations instead of the present letter designations for various classes of forgings.

Subcommittee IX on Steel Tubing and Pipe (T. G. Stitt, chairman).—The various advantages of designating wall thicknesses by decimals in place of B.w.g. and fractions in the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 36) and in the Tentative Specifications for Seamless Steel Boiler Tubes for High-Pressure Service (A 192 – 36 T), as well as the desirability of indicating permissible variations for wall thickness and weight in percentages rather than by the existing dual system, have resulted in proposed revisions[2] of these two specifications. The subcommittee has discussed the changes at several meetings. It is believed that the proposals, which also involve some consolidation of existing tables, represent a very constructive move. Consideration will be given further to decreasing the wall-thickness tolerances. For the sake of completeness, revised tables of permissible variations for cold-drawn tubes are being proposed in Specifications A 83 and A 192 and a restriction limiting the allowable eccentricity in any one tube.

In the near future, Subcommittee IX will offer new specifications for medium-carbon boiler and superheater tubes[2] to replace the present Grade C covered in Specifications A 83. While progress has been made in drafting specifications for three types of spiral pipe[2] now being manufactured, the section in charge has been unable to incorporate requirements for all three in a single specification. Further study is being made. Requirements for carbon-molybdenum boiler and superheater tubes[2] are being drafted and when they are completed the committee plans to consider specifications for other alloy-steel tubes.

The incorporation of assumed physical properties for design purposes as an appendix to certain of the specifications for tubing is being studied. Contacts are being made with the A.S.M.E. Boiler Code Committee.

The subcommittee wishes to direct attention to the approval given by Committee A-1 in 1937 of an editorial change in the Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 36), and for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A 120 – 36), as given in the Appendix to this report, providing for the addition of a note and an appendix referring to a system of standard pipe sizes which has been approved by the American Standards Association as American Tentative Standard for Wrought-Iron and Wrought-Steel Pipe (A.S.A. No.: B36.10 – 1935).

Subcommittee XI on Boiler Steel (E. J. Edwards, chairman).—Increasing use of the three tentative specifications for alloy-steel plates for boiler and other pressure vessels (A 201, A 202, A 204), which are recommended for adoption as standard, has indicated their acceptability. Recommended action is based on this fact plus the desire of the A.S.M.E. Boiler Code Committee that they become standard. Attention is called to an editorial change in connection with the marking clauses of the specifications covering molybdenum-steel plates (A 204), and low-carbon-nickel steel plates (A 203), as given in the Appendix, providing respectively for the use of the letters "MO" instead of the word "molybdenum" and for the letters "NI" instead of the word "nickel."

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[1] See p. 586.

[2] See Editorial Note, p. 66.

In order to bring up to date the widely used Specifications for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 – 36), and the Specifications for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates Over 2 in. to 4 in., Inclusive, in Thickness) (A 150 – 36), revisions proposed in 1937 are recommended for adoption, with minor editorial changes in the titles and scopes as given in the Appendix to this report.

Progress is being made in developing standardized requirements for high-tensile strength steel rivets for boilers; and proposed specifications for nickel-steel and manganese-vanadium-steel rivets are being discussed. Likewise, manganese-vanadium-steel plates for boilers and other pressure vessels are being considered.

Subcommittee XIII on Methods of Physical Tests (L. H. Fry, chairman).—This committee has discussed at length the recommendations of the Research Committee on Yield Point of Structural Steel as presented in its final report in 1937.[1] While the subcommittee was inclined to agree with the Research Committee that in the tension testing of steel the rate of loading is preferable to the free crosshead speed as a method for limiting the speed of testing in the determination of the yield point, later evidence correlated by the chairman indicates that rate of strain does not have a preponderant advantage over rate of crosshead travel for limiting the rate of pulling. The subcommittee recommends that the various subcommittees of Committee A-1 be requested to study the applicability of these methods to the specifications under their jurisdiction.

Following an extended discussion of bend test methods it was decided that Committee A-1 should be asked to request Committee E-1 on Methods of Testing to change the title of the Tentative Method of Bend Testing for Ductility of Metals (E 16 – 31 T) to indicate that it applies to tests for welds only, in order to avoid conflict with the well-established bend test methods in the specifications under the jurisdiction of Committee A-1.

Subcommittee XXI on Steel for Welding (N. L. Mochel, chairman).—Two active matters are being developed by this subcommittee, the first involving changes which have been suggested in the Tentative Specifications for Iron and Steel Filler Metal (A 205 – 37 T) and the second, the review of existing standards and tentative standards under the jurisdiction of Committee A-1 from the viewpoint of welding. It is planned to offer suggestions to the other subcommittees as to the changes that should be made in those specifications to cover satisfactorily welding considerations.

Subcommittee XXII on Valves, Fittings, Piping and Flanges for High-Temperature Service (A. E. White, chairman).—Several revisions are being proposed by this subcommittee in a number of specifications in its charge involving various steel products for high-temperature service. It is believed that these modifications, as listed in the Appendix,[1] are self-explanatory. In general, they are being recommended in order to keep the specifications up to date in this field in which developments are rapid and numerous.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 87 (1937).

Two new intermediate grades of chromium-molybdenum alloy steel are being considered for eventual inclusion in the Standard Specifications for Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 – 36) and requirements for two new specifications covering welding grades of carbon-steel castings and carbon-molybdenum alloy-steel castings, have been drafted. Before action is requested, further study is to be made on the amounts of impurity elements present and matters of welding technique. A section has been appointed to draft specification requirements for welding end fittings.

The election of officers for the ensuing term of two years resulted in the selection of N. L. Mochel, chairman; W. M. Barr, vice-chairman; the re-election of E. F. Kenney, vice-chairman; and H. P. Bigler, secretary.

This report has been submitted to letter ballot of the committee, which consists of 211 members; 128 members returned their ballots, of whom 127 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

H. H. MORGAN,
Chairman.

H. P. BIGLER,
Secretary.

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[1] See pp. 1310 to 1313.

EDITORIAL NOTE

Subsequent to the annual meeting Committee A-1 on Steel presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Specifications for:

Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes, see p. 550.

Medium-Carbon Seamless Steel Boiler and Superheater Tubes, see p. 543.

Spiral Welded Steel or Iron Pipe, see p. 543.

Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes, to replace immediately Standard Specifications A 83 – 36, see p. 531.

Proposed Revision of Tentative Specifications for:

Seamless Steel Boiler Tubes for High-Pressure Service (A 192 – 36 T), see p. 537.

Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A 194 – 38 T), see p. 560.

Proposed Tentative Revision of Standard Specifications for:

Electric-Fusion-Welded Steel Pipe (Sizes 30 in. and Over) (A 134 – 36), see p. 1309.

Electric-Fusion-Welded Steel Pipe (Sizes 8 in. to but not Including 30 in.) (A 139 – 36), see p. 1309.

Billet-Steel Concrete Reinforcement Bars (A 15 – 35), see p. 1310.

Axle-Steel Concrete Reinforcement Bars (A 160 – 36), see p. 1310.

Withdrawal of Standard:

Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 36).

These recommendations were accepted by Committee E-10 and appear in this volume on the pages given above.

APPENDIX

PROPOSED REVISIONS IN STANDARDS FOR STEEL

In this Appendix are given proposed revisions in specifications covering steel and steel products as referred to earlier in this report. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

Revisions of Tentative Standards

Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 37 T):[1]

Section 11.—Change the first sentence to read as follows by the addition of the italicized word:

11. For pipe over 2 in. in nominal diameter, a section of pipe not less than $2\frac{1}{2}$ in. in length shall be flattened *cold* between parallel plates until the opposite walls of the pipe meet.

Tentative Specifications for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T):[1]

Section 5.—Change to read as follows by the omission of the two sentences in brackets:

5. The finished pipe shall be furnished in the normalized and drawn condition unless otherwise specified in the purchase order. [Normalizing shall consist of reheating the finished pipe to 1650 F. and cooling in still air to 800 F. or below. Drawing shall consist of reheating the normalized pipe to 1200 F. and allowing to cool slowly in still air.]

Tentative Specifications for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A 194 – 36 T):[2,3]

Section 1 (b).—Change to read as follows by the addition of the italicized material:

(*b*) Five classes of material for services varying in degree of severity are covered: Class O for service under the least exacting conditions, Class*es 3 and 4* for service under the most severe conditions, and Classes 1, 2 and 2H for service conditions between these extremes.

Section 2.—At the end of this section add a sentence to read as follows:

In all cases, whether a certification of test or the results of the physical tests are furnished, there shall be furnished when required in the purchase order a report giving the minimum drawing temperature for nuts of Classes 2H, 3 and 4.

Section 4 (c).—Change to read as follows by the addition of the italicized words and figures and the omission of the word in brackets:

(*c*) Classes 2H, [and] 3 *and 4* nuts shall be made by the hot forged or cold processes, or machined from hot-forged or hot-rolled bars and shall be heat treated to meet the required physical properties. *These classes of nuts shall be quenched and drawn at a temperature at least 100 F. above the service temperature, but in no case less than 850 F. for Classes 2H and 3 and not less than 1100 F. for Class 4 nuts.*

Section 6.—Change to read as follows by the addition of the italicized word and figure and the omission of the word in brackets:

6. Classes 0, 1, 2, 2H [and] 3 *and 4* analyses will be furnished the purchaser only when specified on the order, and shall conform to the following requirements as to chemical composition for the respective classes.

To the table of chemical composition add the following requirements for a new grade of alloy-steel nut designated as Class 4:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 622, 633 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 140, 151.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 634 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 135.

[3] See Editorial Note, p. 66.

	CLASS 4
Carbon, per cent	0.40 to 0.50
Manganese, per cent	0.50 to 0.95
Molybdenum, min., per cent	0.20
Silicon, min., per cent	0.15
Phosphorus, max., per cent	0.04
Sulfur, max., per cent	0.05

Section 9.—Change Paragraphs (*b*) and (*c*) to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*b*) Samples of each class of nuts, except Class 0 shall show the Brinell hardness specified below: (1) in the finished condition; (2) after the sample has been subjected for 24 hr. to a temperature of 850 F. (455 C.) for Class 1, 1000 F. (540 C.) for Classes 2 and 2H, and 1100 F. (590 C.) for Class*es* 3 *and 4*, and then cooled slowly:

	[MINIMUM] BRINELL HARDNESS	
CLASS	SAMPLE NUT AS FINISHED	SAMPLE NUT AFTER TREATMENT AS IN PARAGRAPH (*b*)
1	150 *min.*	150 *min.*
2	160 *min.*	160 *min.*
2H	[250] *248 to 352*	180 *min.*
3	[250] *248 to 352*	200 *min.*
4	*248 to 352*	*200 min.*

> (*c*) Brinell hardness tests shall be made *on the side of the nut* in accordance with the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.

Section 10.—Change the first sentence of this section to read as follows by the addition of the italicized words:

> 10. *Classes 2H, 3 and 4 nuts when machined from bar stock, and all other classes of* nuts shall be capable of meeting the following drift test: A conical mandrel, part of which has a diameter equal to the nominal nut size, shall be forced through the tapped hole to the nominal nut size, cold, without cracking the body of the nut.

Section 11.—Change the first sentence of this section to read as follows by the addition of the italicized word and figure and the omission of the word in brackets:

> 11. Nuts of Classes 1, 2, 2H, [and] 3 *and 4* shall be capable of meeting the following stripping test: A nut shall be assembled on a piece of bolting material held in a tension testing machine so that a load is applied to the nut.

Section 16 (*b*).—To the table on marking, add requirements for the marking of Class 4 nuts, requiring nuts hot forged or cold punched to be marked "4," and nuts made from bar stock to be marked "4B."

Editorial Changes in Standards

Tentative Specifications for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204 - 37 T):[1]

Section 15 (*a*).—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> Except as specified in Paragraph (*b*), the name or brand of the manufacturer, the manufacturer's test identification number, class, lowest tensile strength specified in Section 7 (*a*) for the grade ordered, and the [word "molybdenum"] *letters* "*MO*" shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end.

Standard Specifications for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 - 36):[2]

Title.—An editorial change in the proposed tentative revision[3] of the title is recommended by the addition of the italicized word, the revised title to read as follows:

> Standard Specifications for High Tensile Strength Carbon-*Silicon*-Steel Plates for Boilers and Other Pressure Vessels (Plates 2 in. and Under in Thickness).

Section 1.—An editorial change in the proposed tentative revision[2] of this section is recommended by the addition of the italicized word in the first sentence, the revised sentence to read as follows:

> These specifications cover two high tensile strength ranges of carbon-*silicon*-steel plates, designated Grades A and B; up to 2 in., inclusive, in thickness; of flange and ordinary firebox qualities; for use in locomotive boiler shells, boilers for stationary service and other pressure vessels.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 582 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 28.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 63.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1303 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1561.

Standard Specifications for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates over 2 in. to 4 in., Inclusive, in Thickness) (A 150 - 36):[1]

Title.—An editorial change in the proposed tentative revision[2] of the title is recommended by the addition of the italicized word, the revised title to read as follows:

> Standard Specifications for High Tensile Strength Carbon-*Silicon*-Steel Plates for Boilers and Other Pressure Vessels (Plates over 2 to $4\frac{1}{2}$ in., Inclusive, in Thickness).

Section 1.—An editorial change in the proposed tentative revision[2] of this section is recommended by the addition of the italicized word in the first sentence, the revised sentence to read as follows:

> These specifications cover two high tensile strength ranges of carbon-*silicon*-steel plates, designated as Grades A and B, over 2 to $4\frac{1}{2}$ in., inclusive, in thickness but not exceeding 25,000 lb. theoretical weight for plates over $4\frac{1}{4}$ to $4\frac{1}{2}$ in., inclusive, in thickness; of ordinary firebox quality; for use in boilers and other pressure vessels.

Standard Specifications for Welded and Seamless Steel Pipe (A 53 - 36):[3]

Section 1 (a).—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> 1. (*a*) These specifications cover ["standard weight," "extra strong," and "double extra strong"] *black and hot-dipped-galvanized furnace*-welded and seamless steel pipe.

Section 12 (a).—Add a note at the end of Paragraph (*a*) to read as follows:

> NOTE.—A system of standard pipe sizes has been approved by the American Standards Association as American Tentative Standard for Wrought-Iron and Wrought-Steel Pipe (A.S.A. No.: B36.10–1935) which dispenses with the double-extra-strong weight and reclassifies the standard and extra-strong weights, substituting therefor schedules of wall thicknesses based on minimum pressure-stress ratios. Wall thicknesses corresponding to most of these now listed as standard weight and extra strong are incorporated in Schedules Nos. 40 and 80, respectively, of the American Tentative Standard B36.10–1935. For information, the schedules of nominal sizes and wall thicknesses (Table 2 of the American Tentative Standard B36.10–1935) are reproduced as an Appendix to these specifications.

Appendix.—Add an Appendix to these specifications to read as follows:

> The accompanying table is a reprint of Table 2 of the American Tentative Standard for Wrought-Iron and Wrought-Steel Pipe (A.S.A. No.: B36.10–1935) of the American Standards Association, which is referred to in the Note under Section 12 (*a*) of these specifications. For the corresponding weights, also the specifications for pipe approved by the American Standards Association, reference should be made to the American Tentative Standard B36.10–1935. Copies of the American Tentative Standard are available from the American Standards Association and the American Society of Mechanical Engineers, 29 W. Thirty-ninth St., New York City; and the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.

Standard Specifications for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A 120 - 36):[4]

Section 1.—Change the first sentence to read as follows by the omission of the words in brackets:

> These specifications cover black and hot-dipped galvanized ["standard weight," "extra strong," and "double extra strong"] welded and seamless steel pipe.

Section 10 (a).—Add a note at the end of Paragraph (*a*) to read the same as the note recommended above in Section 12 (*a*) of Specifications A 53.

Appendix.—Add an Appendix to these specifications to read the same as the Appendix recommended above in Specifications A 53.

Tentative Specifications for Low-Carbon-Nickel Steel Plates for Boilers and Other Pressure Vessels (A 203 - 37 T):[5]

Section 14 (a).—Change the first sentence to read as follows by the addition

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 68.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1304 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1562.

[3] 1936 Book of A.S.T.M. Standards, Part I, p. 289.

[4] 1936 Book of A.S.T.M. Standards, Part I, p. 295.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 577 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 23.

DIMENSIONS OF WELDED AND SEAMLESS PIPE

Nominal Pipe Size, in.	Outside Diameter, in.	Nominal Wall Thicknesses for Schedule Numbers, in.									
		Sched. 10	Sched. 20	Sched. 30	Sched. 40	Sched. 60	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160
$\frac{1}{8}$	0.405	.....	.....	.....	**0.068**	.....	**0.095**	.....	.....	.....	.....
$\frac{1}{4}$	0.540	.....	.....	.....	**0.088**	.....	**0.119**	.....	.....	.....	.....
$\frac{3}{8}$	0.675	.....	.....	.....	**0.091**	.....	**0.126**	.....	.....	.....	.....
$\frac{1}{2}$	0.840	.....	.....	.....	**0.109**	.....	**0.147**	.....	.....	.....	0.18
$\frac{3}{4}$	1.050	.....	.....	.....	**0.113**	.....	**0.154**	.....	.....	.....	0.218
1	1.315	.....	.....	.....	**0.133**	.....	**0.179**	.....	.....	.....	0.250
$1\frac{1}{4}$	1.660	.....	.....	.....	**0.140**	.....	**0.191**	.....	.....	.....	0.250
$1\frac{1}{2}$	1.900	.....	.....	.....	**0.145**	.....	**0.200**	.....	.....	.....	0.281
2	2.375	.....	.....	.....	**0.154**	.....	**0.218**	.....	.....	.....	0.343
$2\frac{1}{2}$	2.875	.....	.....	.....	**0.203**	.....	**0.276**	.....	.....	.....	0.375
3	3.5	.....	.....	.....	**0.216**	.....	**0.300**	.....	.....	.....	0.437
$3\frac{1}{2}$	4.0	.....	.....	.....	**0.226**	.....	**0.318**	.....	.....	.....	.....
4	4.5	.....	.....	.....	**0.237**	.....	**0.337**	.....	0.437	.....	0.531
5	5.563	.....	.....	.....	**0.258**	.....	**0.375**	.....	0.500	.....	0.625
6	6.625	.....	.....	.....	**0.280**	.....	**0.432**	.....	0.562	.....	0.718
8	8.625	.....	0.250	**0.277**	**0.322**	0.406	**0.500**	0.593	0.718	0.812	0.906
10	10.75	.....	0.250	**0.307**	**0.365**	**0.500**	0.593	0.718	0.843	1.000	1.125
12	12.75	.....	0.250	**0.330**	0.406	0.562	0.687	0.843	1.000	1.125	1.312
14 O. D.	14.0	0.250	0.312	0.375	0.437	0.593	0.750	0.937	1.062	1.250	1.406
16 O. D.	16.0	0.250	0.312	0.375	0.500	0.656	0.843	1.031	1.218	1.437	1.562
18 O. D.	18.0	0.250	0.312	0.437	0.562	0.718	0.937	1.156	1.343	1.562	1.750
20 O. D.	20.0	0.250	0.375	0.500	0.593	0.812	1.031	1.250	1.500	1.750	1.937
24 O. D.	24.0	0.250	0.375	0.562	0.687	0.937	1.218	1.500	1.750	2.062	2.312
30 O. D.	30.0	0.312	0.500	0.625	.....	.....	.....	.....	.....	.....	.....

All dimensions are given in inches.

The decimal thicknesses listed for the respective pipe sizes represent their nominal or average wall dimensions and include an allowance for mill tolerance of 12.5 per cent under the nominal thicknesses.

Thicknesses shown in bold face type in Schedules 30 and 40 are identical with thicknesses for "standard weight" pipe in former lists; those in Schedules 60 and 80 are identical with thicknesses for "extra-strong" pipe in former lists.

The Schedule Numbers indicate approximate values of the expression 1000 × P/S.

of the italicized words and the omission of those in brackets:

14. (*a*) Except as specified in Paragraph (*b*), the name or brand of the manufacturer, the manufacturer's test identification number, class, lowest tensile strength specified in Section 6 (*a*) for the grade ordered, and the [word "nickel"] *letters "NI"* shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end.

REPORT OF SECTIONAL COMMITTEE

ON

STANDARDIZATION OF DIMENSIONS AND MATERIALS OF WROUGHT-IRON AND WROUGHT-STEEL PIPE AND TUBING

A.S.A. PROJECT: B36

The Sectional Committee on Standardization of Dimensions and Materials of Wrought-Iron and Wrought-Steel Pipe and Tubing held one meeting during the past year, in Rochester, N. Y., on March 8, 1938.

The committee approved the addition of the following A.S.T.M. specifications to Table I on Specifications for Pipe of the American Tentative Standard for Wrought-Iron and Wrought-Steel Pipe (A.S.A. No. B 36.10–1935):

Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 37 T),

Tentative Specifications for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T), and

Standard Specifications for Electric-Fusion-Welded Steel Pipe for High-Temperature and High-Pressure Service (A 155 – 36).

Specifications A 155 – 36 will be referred to letter ballot of the sectional committee for submission to the American Standards Association for approval as an American standard.

Since the pipe standard has had a tentative status for nearly three years with little revision other than that necessary to keep it abreast of new specifications formulated for pipe, the committee recommends that the American Tentative Standard for Wrought-Iron and Wrought-Steel Pipe (B 36.10–1935) be submitted to the American Standards Association for approval as American standard.

While the degree of acceptance and extent of use of the standard since its approval in 1935 have not proceeded as fast as desired, the standard is being used to good advantage for high-pressure high-temperature piping in central stations. The A.S.T.M. Tentative Specifications for Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T) contain two series of wall thicknesses for carbon-molybdenum pipe which were selected from the schedules of Standard B 36.10. The Standard Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 36) contain the entire table of schedule wall thicknesses to facilitate selection of pipe in accordance with the B 36 Standard. The A.S.T.M. Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 36) and for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A 120 – 36) are being revised to include as an appendix the B 36 table on wall thicknesses until the more extensive use of the standard for the ordinary run of pipe warrants inclusion of the schedules in the text, in place of the present tables of standard weight and extra-strong pipe.

Every effort is being made to familiarize the piping trade with the B 36 standard by having articles appear in trade publications stressing the advantages to be derived from its use. The committee will earnestly endeavor to encourage wider acceptance and use of the schedules by continued education of distributors, jobbers, and users of pipe.

This report has been submitted to letter ballot of the committee which consists of 41 members; 40 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. H. MORGAN,
Chairman.

SABIN CROCKER,
Secretary.

REPORT OF COMMITTEE A-2

ON

WROUGHT IRON

Committee A-2 on Wrought Iron held one meeting during the year, in Rochester, N. Y., on March 7, 1938. A second meeting will be held prior to the presentation of this report to the Society when the report will be reviewed and other matters considered.

During the year, there have been changes in the representation of several company members. Mr. A. F. Nertney has been appointed as the representative of the Cohoes Rolling Mill in place of Mr. P. C. Doerr, resigned; Mr. O. W. Hovis as the representative of the Tennessee State Highway Department in place of Mr. E. W. Bauman, resigned; and Mr. B. O. Hickman to represent the Ewald Iron Company in place of Mr. G. O. Boomer, resigned.

The present membership of the committee now totals 58, of whom 20 are classified as producers, 30 as consumers, and 8 as general interest members.

Subsequent to the 1937 annual meeting, Committee A-2 presented to the Society on August 26, 1937, through Committee E-10 on Standards the recommendations listed below, all of which were accepted[1] for publication as tentative:

Tentative Revision of Standard Specifications for:

- Iron and Steel Chain (A 56 – 30),
- Staybolt Wrought Iron, Solid (A 84 – 36),
- Staybolt Wrought Iron, Hollow Rolled (A 86 – 36), and

Tentative Specifications for Rolled Wrought-Iron Shapes and Bars (A 207 – 37 T).

The tentative revisions and new tentative specifications appear in the 1937 *Proceedings*.[2]

Recommendations Affecting Standards

Revision of Standard:

The committee is recommending for immediate adoption, a revision in the table of hydrostatic pressures appearing in the Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 33).[3] The changes, as explained below, are necessary in order to correct errors which through oversight have appeared in the present and several previous issues of these standard specifications. The committee accordingly asks for the necessary nine-tenths vote at the annual meeting in order that this modification may be referred to letter ballot of the Society for immediate adoption.

Section 3.—Change this section to read as follows by the addition of the italicized figures and the omission of those in brackets:

> 3. All pipe [3] *2* in. or under in nominal diameter may be butt-welded, unless otherwise specified. All pipe over [3] *2* in. in nominal diameter shall be lap-welded.

Table I.—From the butt-weld columns under all three weights of pipe, delete the requirements for hydrostatic pressures applying to pipe sizes 2½ in. and 3 in. in nominal inside diameter, since butt-welded wrought-iron pipe is not made in these two sizes.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee A-2 reported the following results of the letter ballot vote of a total of 41 ballots returned from a committee membership of 59: A 56 – 30, affirmative 30, negative 1, ballots marked "not voting" 10; A 84 – 36, affirmative 36, negative 0, ballots marked "not voting" 5; A 86 – 36, affirmative 35, negative 0, ballots marked "not voting" 6; A 207 – 37 T, affirmative 33, negative 1, ballots marked "not voting" 7.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1307, 1308, 1310, and 664 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1565, 1566, 1568, and 263.

[3] 1936 Book of A.S.T.M. Standards, Part I, p. 432.

From the lap-weld column under double extra-strong pipe, delete the requirement for hydrostatic pressure for pipe size 1½ in. in nominal inside diameter because wrought-iron pipe of this size and weight is made only by the butt-weld process.

Revision of Tentative Standard:

The committee recommends the following revision in the Tentative Specifications for Rolled Wrought-Iron Shapes and Bars (A 207 – 37 T):[1]

Section 2.—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> 2. The shapes, sections, and bars [may] *shall* be direct rolled [from billets] *or rolled from piles* made from pig puddled or processed wrought iron and shall be free from any admixture of iron scrap or steel.

The note following this section is to remain unchanged.

The above recommendations have been submitted to letter ballot of the committee, which consists of 58 members; 54 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. REVISION OF STANDARD			
Specifications for Welded Wrought-Iron Pipe (A 72 – 33), immediate adoption	42	0	12
II. REVISION OF TENTATIVE STANDARD			
Specifications for Rolled Wrought-Iron Shapes and Bars (A 207 – 37 T)	42	0	12

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Tubes and Pipe (G. H. Woodroffe, chairman).—On the recommendation of this subcommittee, the revision in the Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 33), as mentioned earlier in this report, is being recommended for immediate adoption.

This subcommittee has under consideration the inclusion in Specifications A 72, as a matter of information, of a reference to the system of standard pipe sizes covered in the American Tentative Standard for Wrought-Iron and Wrought-Steel Pipe (A.S.A. No.: B 36.10 – 1935). Under this American standard the present classifications according to weight are dispensed with and in place thereof, schedules of wall thicknesses based on minimum pressure-stress ratios are used. This matter is being considered by the subcommittee in the interest of having the pipe specifications consistent in this respect, since a similar reference has been approved by Committee A-1 on Steel for inclusion in the two existing specifications for steel pipe.

Subcommittee II on Wrought-Iron Bars (J. Porter Gillespie, chairman).—This subcommittee held a meeting in Rochester, N. Y., on March 7, at which consideration was given to the tolerances on round wrought-iron bars for staybolts as the result of criticisms which had been received of the tentative revisions of the Standard Specifications for Staybolt Wrought Iron, Solid (A 84 – 36) and the Standard Specifications for Staybolt Wrought Iron, Hollow Rolled (A 86 – 36), accepted for publication by the Society last year as mentioned earlier in this report. It is expected that this matter will be given further consideration by the subcommittee during the year.

The subcommittee also reviewed a proposed revision of the Federal Specifications for Refined Wrought Iron Bars (QQ-I-686), which had been received through the Society headquarters, for comment. As a result of this consideration, several suggestions respecting the specifications were approved for submission to the Federal Specifications Board and it was also considered desirable to call to the attention of the F.S.B. committee, the A.S.T.M. Tentative Specifications for Single- and Double-Refined Wrought-Iron Bars (A 189 – 37 T), as covering material of interest in connection with the Federal specifications.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 664 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 263.

Subcommittee IV on Plates, Shapes and Sheets (James Aston, chairman).—This subcommittee held a meeting in Rochester, N. Y., on March 7 at which time consideration was given to the two specifications under its jurisdiction, namely, the Tentative Specifications for Rolled Wrought-Iron Shapes and Bars (A 207 – 37 T) and Tentative Specifications for Wrought-Iron Plates (A 42 – 37 T). As mentioned earlier in this report, a revision, which has been approved by letter ballot of the subcommittee, is being recommended in Specifications A 207.

In Specifications A 42, an editorial change will be made to indicate that the tensile properties provided for in Section 5 are intended to apply to the requirements in Section 4 (*a*) of the specifications. This will involve the addition to the table of requirements in Section 4 (*a*) of footnote references such as are used in Section 4 (*d*).

The election of officers, held at the Rochester meeting of the committee, resulted in the election of the following for the ensuing term of two years:

Chairman, C. B. Bryant, Engineer of Tests, Southern Railway System,
Vice-Chairman, James Aston, Consulting Metallurgist, A. M. Byers Co., and
Secretary, W. C. Masters, Eastern Sales Manager, the Flannery Bolt Co.

This report has been submitted to letter ballot of the committee, which consists of 58 members; 54 members returned their ballots, of whom 45 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

J. B. YOUNG,
Chairman.

G. H. WOODROFFE,
Secretary.

REPORT OF COMMITTEE A-3
ON
CAST IRON

Since the 1937 annual meeting of the Society, Committee A-3 on Cast Iron has held one meeting in Rochester, N. Y., on March 9, 1938. A second meeting will be held in June during the annual meeting of the Society.

It is with regret that the committee records the loss through death of a long-time member, J. A. Capp, Engineer of Materials, Works Laboratory, General Electric Co., Schenectady, N. Y. Mr. Capp had been very active in committee work, and his loss will be keenly felt.

Four members have resigned, which brings the total personnel of the committee to 97 members, of whom 25 are classified as producers, 40 as consumers, and 32 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

Tentative Revision of Standard:

The committee recommends for publication as tentative, a revision of the Standard Specifications for Gray-Iron Castings for Valves, Flanges, and Pipe Fittings (A 126 – 30),[1] as follows:

Section 1.—Change the second paragraph to read as follows by the addition of the italicized words and the omission of the word in brackets:

> [Two] *Three* classes of castings are included as follows:
>
> Class A.—Regular gray iron.
>
> Class B.—Higher-strength gray iron including the so-called semi-steels used in valves and fittings.
>
> *Class C.—High-test cast iron, whether regular or alloy composition.*

Section 4 (a).—Change the table of tensile strength requirements to read as shown in Table I by the addition of the italicized words and figures and the omission of the figure in brackets.

TABLE I.

Class A, Regular gray iron	not less than 21 000 lb. per sq. in.
Class B, Higher-strength gray iron	not less than [30 000] *31 000* lb. per sq. in.
Class C	*not less than 41 000 lb. per sq. in.*

TABLE II.

	Class A REGULAR GRAY IRON	*Class B* HIGHER-STRENGTH GRAY IRON	*Class C*
Load at center, lb.	not less than [2500] *2200*	not less than 3300	*not less than 4000*
Deflection at center, in.	not less than 0.10	not less than 0.12	*not less than 0.12*

Section 5 (a).—Change the table of transverse strength requirements to read as shown in Table II by the addition of the italicized words and figures and the omission of the figure in brackets.

Adoption of Tentative Standard as Standard:

The committee recommends the adoption as standard of the Tentative Specifications for Cast-Iron Culvert Pipe (A 142 – 35 T)[2] with the following revisions:

Section 4.—Change the first sentence of this section to read as follows by the addition of the italicized word:

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 465.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 720 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 275.

> The pipe shall be manufactured of *gray* cast iron of good quality and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to admit satisfactorily of drilling and cutting.

Section 7 (b).—Omit this section which reads as follows, relettering the subsequent paragraph accordingly:

> (*b*) The metal in the barrel of the finished pipe shall contain not more than 0.90 per cent of combined carbon. The test sample for the determination of combined carbon shall be composed of drillings representative of the full thickness of the pipe barrel.

Section 8 (b).—Change this section to read as follows by the addition of the italicized words and the omission of the words in brackets:

> (*b*) *Full-length* pipe specimens tested for strength shall not be tested to destruction if they will sustain, without cracking, a load 10 per cent in excess of the specified load. If the purchaser desires [tests] *that full-length specimens be tested* to destruction he shall specify [on] *in* the order the number of such tests which will be required.

Add a new Paragraph (*c*) and note to this section to read as follows:

> (*c*) Ring specimens cut from the spigot ends of pipe shall be tested to destruction.
>
> NOTE.—See Section 13 for a description of types of test specimens.

Section 11.—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> 11. The purchaser may require strength tests in such numbers as he may deem necessary, provided that if the pipe meets the requirements as to shell thickness and weight, the number of specimens tested, *unless otherwise specified in the purchase order*, shall not exceed [three] *one* pipe or 5 per cent, whichever may be larger, of each size and class ordered. [In placing an order the purchaser shall specify the number of strength tests which will be required.]

Section 13.—Change this section from its present form: namely,

> 13. The laying length of test specimens of pipe shall be not less than 3 nor more than 4 ft. If the manufacturer proposes to furnish, for use in the work, pipe having a length greater than 4 ft., he shall furnish for the required tests a sufficient number of test specimens of the required length.

to read as follows:

> 13. Test specimens of pipe may be of two types. If the pipe to be furnished has a laying length of 4 ft. or less the test specimens shall be full-length sections of pipe. If the pipe to be furnished has a laying length greater than 4 ft. the test specimens shall be rings cut from the spigot ends of the pipe and shall be not less than 1 ft. nor more than 4 ft. in length. Within these limits the length of ring specimens furnished shall be at the discretion of the manufacturer.

Section 14.—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> 14. (*a*) *Full-length* pipe specimens shall be tested under a load 10 per cent in excess of the load specified [for the particular class of pipe]. Shipments represented by *full-length* specimens which sustain the specified load without the development of cracks shall be accepted as fulfilling the strength requirements. *Full-length test* specimens [of pipe] which meet all other requirements of the specifications and which sustain a load 10 per cent in excess of that specified without the development of cracks shall be accepted for use.
>
> (*b*) *If ring specimens cut from the spigot ends of pipe meet the strength requirements, the pipe from which they have been cut shall be acceptable to the purchaser provided that they are of suitable length and meet all other requirements of these specifications.*
>
> (*c*) The cost of *full-length pipe* specimens which fail to sustain the specified load, or a load 10 per cent in excess of that specified, *and the cost of ring specimens cut from the spigot ends of pipe*, shall be borne by the manufacturer.
>
> NOTE.—It is recommended that a *full-length* test specimen which has been accepted for use be marked with a suitable identification symbol and be installed in the culvert structure in such location as will subject it to the least severe loading.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 97 members, the results being given in Table I.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee II on Pipe has been disbanded and two new subcommittees, one on Soil Pipe and one on Pressure Pipe, are being organized to replace it.

Subcommittee VI on General Castings (J. W. Bolton, chairman).—This subcommittee has appointed a new subgroup to investigate the 2-in. bar in the 60,000-lb. class of irons.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. TENTATIVE REVISION OF STANDARD			
Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings (A 126 – 30)............	64	1	10
II. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Specifications for Cast-Iron Culvert Pipe (A 142 – 35 T), as revised..............................	43	1	13

Subcommittee VIII on Cast-Iron Culvert Pipe (E. F. Kelley, chairman).—This subcommittee is recommending the adoption as standard of the Tentative Specifications for Cast-Iron Culvert Pipe (A 142 – 35 T) with revisions as given earlier in this report.

Subcommittee XVII on Gray-Iron Castings for Valves, Flanges and Pipe Fittings (J. J. Kanter, chairman).—This subcommittee is recommending a tentative revision, as given earlier in this report, of the Standard Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings (A 126 – 30).

Subcommittee XIX on Chilled- and White-Iron Castings (Johannes Erler, chairman).—This subcommittee was organized at a meeting held in March, 1938, and will investigate the properties of chilled- and white-iron castings.

The following officers have been unanimously elected for the ensuing term of two years:

Chairman, W. H. Rother
Vice-Chairman, Robert Job
Secretary, H. C. Aufderhaar

This report has been submitted to letter ballot of the committee which consists of 97 members; 62 members returned their ballots, of whom 60 have voted affirmatively and 2 negatively.

Respectfully submitted on behalf of the committee,

W. H. ROTHER,
Chairman.

H. C. AUFDERHAAR,
Secretary.

REPORT OF COMMITTEE A-5
ON
CORROSION OF IRON AND STEEL

Committee A-5 on Corrosion of Iron and Steel has held two meetings during the past year: one on June 30, 1937, during the annual meeting of the Society in New York City, and the other on March 10, 1938, at the spring group meeting of A.S.T.M. committees in Rochester, N. Y.

Since the last report, 1 new member has been elected and 4 members have resigned; the committee membership now totals 124, of whom 55 are classified as producers, 43 as consumers, and 26 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

The committee recommends that the proposed Tentative Method of Test for Uniformity of Coating by the Copper Sulfate Dip Test (Preece Test) on Zinc-Coated (Hot-Galvanized) Steel Castings and Forgings, Gray-Iron and Malleable-Iron Castings be accepted for publication as tentative, as appended hereto.[1] This proposed tentative standard has been prepared to supply a method for determining the weight of coating on irregularly shaped hardware specimens and is needed for use in connection with the Tentative Specifications for Zinc Coating (Hot-Dip) on Hardware and Fastenings (A 153 - 33 T). The new test is necessary as the Tentative Method of Test for Uniformity of Coating by the Preece Test (Copper Sulfate Dip) on Zinc-Coated (Galvanized) Iron or Steel Wire (A 191 - 36 T) and the Preece Test described in the Standard Method of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A 90 - 33) are not suitable for use with the class of hardware to which the new method applies.

Tentative Revision of Standard:

The committee recommends an extensive tentative revision of the Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 - 27) in the form of new tentative specifications appended hereto,[2] which are intended to replace, when adopted, the present standard specifications. The proposed revised specifications do not represent any new technologic advances but differ from the standard specifications in certain details as indicated below under the activities of Subcommittee VI.

Adoption of Tentative Standard as Standard:

The committee recommends that the Tentative Method of Test for Uniformity of Coating by the Preece Test (Copper Sulfate Dip) on Zinc-Coated (Galvanized) Iron or Steel Wire (A 191 - 36 T)[3] be revised as indicated below and approved for reference to letter ballot of the Society for adoption as standard:

Section 2.—Change the third sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

> The fact that different processes of [galvanizing] *applying a zinc coating* produce coatings having widely varying rates of solubility in

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[1] See p. 608.

[2] See p. 602.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 645 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 237.

the copper sulfate solution precludes the use of the Preece test for determining relative weights of coating.

Section 5.—At the end of this section add a sentence to read as follows:

> Running water should be used when available.

Explanatory Notes.—Change the last sentence of Note 2 to read as follows by the addition of the italicized words:

> In all such cases the test specimens shall be cleaned in alcohol, rinsed and wiped dry and then immersed for 3 min. in a solution consisting of one part by volume of ammonium hydroxide (sp. gr. 0.90) and nine parts of water, during which time the specimens may be scrubbed with cotton waste; after cleaning, the specimens shall be washed and wiped dry *and then tested in accordance with the procedure given in Section 8.*

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 124 members; 97 members returned their ballots, the results being shown in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Method of Test for Uniformity of Coating by the Copper Sulfate Dip Test (Preece Test) on Zinc-Coated (Hot-Galvanized) Steel Castings and Forgings, Gray-Iron and Malleable-Iron Castings....	85	0	12
II. TENTATIVE REVISION OF STANDARD			
Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 – 27)........................	83	2	12
III. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method of Test for Uniformity of Coating by the Preece Test (Copper Sulfate Dip) on Zinc-Coated (Galvanized) Iron or Steel Wire (A 191 – 36 T), as revised....................................	91	0	6

ACTIVITIES OF SUBCOMMITTEES

Subcommittee III on Inspection of Annapolis Tests (E. S. Taylerson, chairman).—Since the inspection on October 16, 1936, the subcommittee has held two meetings at Annapolis, Md. On May 3, 1937, six failures were observed, namely, B26 (open-hearth steel), C15, C25 (copper-bearing pure open-hearth iron), E6 (copper-bearing puddled iron), and M10 (copper-bearing open-hearth iron). On October 29, 1937, six failures were observed, namely, E10, E11 (copper-bearing puddled iron), H18 (copper-bearing open-hearth steel), U7, U13 (copper-bearing pure open-hearth iron), and V1 (copper-bearing pure open-hearth iron). All of the failures recorded up to this time are in the No. 22 gage material. A summary of the failures to date is given in the accompanying Table II.

Subcommittees V on Total Immersion Tests (W. J. Jeffries, chairman).—The subcommittee has continued its inspections in the field and plans to present next year a detailed report and analysis of the observations to date.

Subcommittee VI on Specifications for Metallic-Coated Products (W. H. Finkeldey, chairman).—Subcommittee VI has held two meetings during the past year. It has prepared and presented to Committee A-5 a revision of the Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 – 27) in the form of new tentative specifications, as appended hereto,[1] which are intended to replace, when adopted, the present standard specifications. The new specifications are similar in scope and arrangement to the standard; they are general specifications covering sheets with ordered weights of coating and are not intended to cover tests of commercial coatings for general utility or tight lighter-weight coatings for fabrication. No important technologic advance has been made. Unused features have been removed, coating bend tests amplified

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[1] See p. 602.

TABLE II.—RECORD OF FAILURES IN ATMOSPHERIC EXPOSURE TESTS AT ANNAPOLIS OF NO. 22-GAGE COPPER-BEARING AND NON-COPPER-BEARING CORRUGATED BLACK SHEETS.

Sheets Exposed October 17, 1916. Inspections Made Semiannually from 1917 to 1938.

Group	Designation	Series	Average Analysis, per cent						Number of Sheets in Test[a]	Life of Each Failed Sheet in Years																Number of Sheets in Test[a]	Number of Sheets Failed	Average Life of Sheets in Years	Group
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper																					
Z.....	Open-hearth steel	B	0.032	0.32	0.063	0.042	.....	0.019	3	13.5	17.0	19.0	..	..	..	..	..	..	..	..	..	..	..	..	..	3	3	16.5	......Z
O.....	Open-hearth steel	A	0.121	0.536	0.008	0.030	0.249	0.020	12	7.0	9.0	9.0	9.0	9.0	9.5	10.0	10.0	11.0	11.0	13.0	17.0	..	..	..	..	12	12	10.4	......O
B.....	Open-hearth steel	A	0.09	0.38	0.017	0.062	0.036	0.084	3	20.0	20.5	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	2	....	......B
M....	Open-hearth steel	B	0.093	0.419	0.013	0.041	0.011	0.185	14	20.0	20.5	*	*	*	*	*	*	*	*	*	*	*	*	..	..	14	2	....	......M
B.....	Open-hearth steel	A	0.06	0.27	0.014	0.053	0.006	0.187	9	19.5	20.0	*	*	*	*	*	*	*	..	..	..	..	..	..	..	9	2	....	......B
Z.....	Open-hearth steel	B	0.067	0.351	0.045	0.052	0.003	0.187	3	*	*	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	0	....	......Z
T.....	Open-hearth steel	B	0.083	0.313	0.009	0.020	0.005	0.227	14	19.5	19.5	19.5	*	*	*	*	*	*	*	*	*	*	*	..	..	14	3	....	......T
K.....	Open-hearth steel (acid)	A	0.107	0.447	0.091	0.046	0.004	0.237	16	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	16	0	....	......K
H.....	Open-hearth steel	A	0.069	0.387	0.016	0.027	0.004	0.244	11	19.5	21.0	*	*	*	*	*	*	*	*	*	..	..	..	..	..	11	2	....	......H
Z.....	Open-hearth steel	B	0.065	0.35	0.050	0.059	0.003	0.264	2	*	*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	0	....	......Z
Z.....	Open-hearth steel	B	0.073	0.42	0.052	0.054	Trace	0.641	3	*	*	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	0	....	......Z
S.....	Open-hearth iron	B	0.02	0.023	0.006	0.022	0.004	0.022	14	7.0	8.0	8.5	9.0	9.5	10.0	11.0	11.5	11.5	12.5	12.5	12.5	12.5	12.5	..	..	14	14	10.6	......S
D....	Open-hearth iron	A	0.02	0.026	0.004	0.022	0.002	0.024	6	16.0	16.0	16.0	19.5	19.5	*									..	..	6	5	....	......D
X....	Open-hearth iron	B	0.021	0.055	0.007	0.031	0.004	0.027	14	10.5	13.0	13.5	14.5	14.5	16.0	16.0	16.5	16.5	17.0	17.5	17.5	18.0	19.0	..	..	14	14	15.7	X
C.....	Open-hearth iron	A	0.01	0.028	0.002	0.027	0.002	0.141	3	17.5	20.5	*					..	..	..	..	..	..	..	..	..	3	2	....	C
C.....	Open-hearth iron	A	0.015	0.028	0.006	0.036	0.003	0.194	9	16.5	16.5	18.5	19.0	19.0	20.0	20.5	*	*	..	..	..	..	..	..	..	9	7	....	C
U.....	Open-hearth iron	B	0.017	0.074	0.008	0.037	0.005	0.260	13	15.5	16.5	19.0	19.0	19.0	19.0	19.0	19.5	20.0	20.0	21.0	21.0	*	..	..	..	13	12	....	......U
V.....	Open-hearth iron	B	0.018	0.051	0.007	0.021	0.005	0.304	14	17.0	17.0	17.5	18.5	18.5	19.0	20.0	20.0	20.5	21.0	*	*	*	*	..	..	14	10	....	V
A.....	Bessemer steel	A	0.038	0.386	0.089	0.040	0.007	0.014	15	15.5	16.5	16.5	17.0	17.0	17.0	18.0	19.0	19.0	19.5	19.5	19.5	19.5	19.5	20.0	..	15	15	18.2	......A
Z.....	Bessemer steel	B	0.063	0.41	0.102	0.044	0.009	0.013	3	11.5	11.5	11.5	..	..	..	..	..	..	..	..	..	..	..	..	..	3	3	11.5	......Z
Z.....	Bessemer steel	B	0.077	0.44	0.095	0.036	0.003	0.140	3	*	*	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	0	....	......Z
I.....	Bessemer steel	A	0.041	0.365	0.097	0.068	0.008	0.252	16	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	16	0	....	I
Z.....	Bessemer steel	B	0.058	0.37	0.093	0.043	0.009	0.269	3	*	*	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	0	....	......Z
Z.....	Bessemer steel	B	0.055	0.38	0.110	0.046	....	0.527	3	*	*	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	0	....	......Z
Y.....	Wrought iron	B	0.03	0.055	0.139	0.021	0.218	0.020	3	18.0	19.5	*	..	..	..	..	..	..	..	..	..	..	..	..	..	3	2	....	......Y
E.....	Wrought iron	A	0.033	0.034	0.114	0.021	0.134	0.283	11	19.5	20.5	21.0	21.0	*	*	*	*	*	*	*	..	..	..	..	..	11	4	....	......E
							Total.........		220																Total...	220	114		

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* Indicates unfailed sheets.

[a] The number of sheets in the test indicated in this table is less in some instances than the number shown in similar tables in earlier reports because certain sheets were discarded due to mechanical damage.

gage ranges of the heavier coatings increased and coating weight tests by stripping and spot tests, coordinated. The diagonal triple-spot test method has been retained. A cross-wise triple-spot test made at one end of the sheet has been discussed but this test has been omitted since it has been proposed for culvert sheets only, which in general are made in one width and only in heavy gages and present a special case for which special arrangements could be made.

The Section on Strand is still working on a proposed revision of the Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Wire Strand (Cable) (A 122 – 33). The Section on Chain Link Fence is continuing work on a proposed revision of the Standard Specifications for Zinc-Coated Iron or Steel Chain-Link Fence Fabric Galvanized After Weaving (A 117 – 33) and on the preparation of new specifications for chain-link fence fabric galvanized before weaving. Opposing viewpoints and consideration of products commercially available have necessarily made for slow progress in both sections.

As very few comments have been received, the Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 37 T) and the Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 37 T) are being continued as tentative for another year.

The three tentative specifications covering electrodeposited coatings of zinc (A 164 – 35 T), cadmium (A 165 – 35 T), and nickel and chromium (A 166 – 35 T) on steel, which have had a tentative status for three years, are being continued as tentative for another year. Test methods for determining thickness of coatings have been agreed on by Subcommittee VII but agreement has not yet been reached on methods of sampling. Heavier coatings than those covered by the three specifications mentioned above are already being used and may necessitate adding another class to the specifications.

The Section on Telephone and Telegraph Line Wire and Tie Wires reports that no urgent requests have developed for revision of the present Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire (A 111 – 33) and Tie Wires (A 112 – 33).

A new section is to be appointed to consider necessary revisions of the Tentative Specifications for Zinc Coating (Hot-Dip) on Hardware and Fastenings (A 153 – 33 T) and to coordinate these specifications with the new tentative method of test for uniformity of coating by the Preece test on irregularly shaped hardware specimens, which is being presented this year for publication as tentative on the recommendation of Subcommittee VII.

Subcommittee VII on Methods of Testing (L. W. Hopkins, chairman).—Subcommittee VII has held two meetings during the past year, and in addition, its various technical groups have been quite active. The Tentative Method of Test for Uniformity of Coating by the Preece Test (Copper Sulfate Dip) on Zinc-Coated (Galvanized) Iron or Steel Wire (A 191 – 36 T) has been reviewed by the Section on Preece Test; various minor changes have been incorporated therein, as mentioned earlier in this report, and it is recommended that this method as revised be adopted as standard.

The Section on Testing Galvanized Coatings on Hardware, under the chairmanship of F. L. Wolf, has completed a thorough study of tests for uniformity of coatings on irregularly shaped castings and forgings and has prepared a new Tentative Method of Test for Uniformity of Coating by the Copper Sulfate Dip

Test (Preece Test) on Zinc-Coated (Hot-Galvanized) Steel Castings and Forgings, Gray-Iron and Malleable-Iron Castings, which, as mentioned earlier in this report, is being presented for publication as tentative, as appended hereto.[1] The activities of this section which led up to the promulgation of this standard are fully covered in an article appearing in the May, 1938, issue of the *ASTM Bulletin*.

The Section on Test Methods for Determining Weight and Thickness of Plated Coatings has continued its program, including a study of proposed methods of sampling. It is hoped that this work will be sufficiently far advanced so that the methods may be acted upon by the subcommittee and referred to Committee A-5 prior to the June, 1938, meeting.

Subcommittee VIII on Field Test of Metallic Coatings (R. F. Passano, chairman).—Subcommittee VIII has continued its inspections in the field and has made the first inspections on the wire test specimens. A detailed report of the subcommittee is appended hereto.

Subcommittee X on Embrittlement Investigation (W. G. Kelley, chairman).—Subcommittee X practically completed its work several years ago. By its own request it has, therefore, been discharged.

The following officers of Committee A-5 have been elected for the ensuing term of two years:

Chairman, W. H. Finkeldey
First Vice-Chairman, W. G. Kelley
Second Vice-Chairman, L. W. Hopkins

T. R. Galloway has been reappointed secretary by the new chairman.

This report has been submitted to letter ballot of the committee which consists of 124 members; 100 members returned their ballots, of whom 94 have voted affirmatively and 2 negatively.

Respectfully submitted on behalf of the committee,

F. F. FARNSWORTH,
Chairman.

T. R. GALLOWAY,
Secretary.

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[1] See p. 608.

REPORT OF SUBCOMMITTEE VIII ON FIELD TESTS OF METALLIC COATINGS

Subcommittee VIII has held one general meeting since the 1937 annual meeting of the Society.

There are now three field tests in progress: the first on galvanized sheets; the second on metallic coated hardware, structural shapes, tubular goods, etc.; and the third on wire and wire products. This report presents inspection data from the first two of these field tests gathered since the 1935 report.

The Wire Test Inspection Committee has been organized under the chairmanship of Mr. C. D. Hocker. It has held several exploratory meetings, and as a result has developed inspection forms and a notion of the kind of thing to expect on the wires as they corrode. The wire inspections will produce a larger mass of material than will either of the other field tests. The inspection committee rightly feels that suitable machinery for condensation should be established and worthwhile information collected before it ventures a detailed report. The referee work of characterizing the test specimens is in progress at the National Bureau of Standards by the two research associates employed by the committee for this purpose. The tests being made by these associates are not quite complete, although the bulk of their work has been finished.

The geographical distribution of the eleven wire test locations makes it necessary for the wire inspection committee to depend on resident inspectors for notification of interesting developments at the locality for which each is responsible. A training session for resident-inspectors was held at Lafayette, Ind., on December 3, 1937, and it is very gratifying that all but one of the resident-inspectors were in attendance to learn of their duties, their manner of operation, etc.

Galvanized Sheets:

The previous reports of Subcommittee VIII have included tables summarizing the performance of the zinc coatings on the exposed surfaces at three of the five test locations: namely, Altoona, Pa., Brunot Island (Pittsburgh), Pa., and Sandy Hook, N. J. The coatings on the samples at the fourth test site, State College, Pa., are now starting to fail in the same fashion, and this year's report includes a table to show this beginning after the manner already used on the other three. In general, the behavior of the sheets at these four test locations can be described briefly as follows:

1. The coating protects the upper surface of the metal for a period of years from the elements.

2. The zinc wastes away on the exposed surface, uncovering more and more of the base metal.

3. In the meanwhile, development on the under surface has been slow. The zinc coating on the under surface may have lost some weight, but it has furnished essentially complete protection to the underneath surface of the base metal.

4. The zinc coating fails on the under surface at the drainage or bottom edge.

5. When the zinc is removed on both

the exposed and under surface at the drainage edge, atmospheric attack proceeds from both surfaces, and perforation of the sheet develops after a lapse of time along this drainage edge.

Thus, at the four northern test locations, disappearance of the zinc coating from the exposed surface is a development which precedes failure or perforation of the base sheet by an appreciable length of time. The reports dealing with the four northern locations show the performance of the zinc coatings as the first step of interest in the deterioration, even though it represents only partial destruction of the test specimen.

The nature of the deterioration at the fifth test location, Key West, Fla., is very different from that just described.

TABLE I.—TIME REQUIRED FOR APPEARANCE OF RUST ON SAMPLES AT FOUR NORTHERN TEST LOCATIONS.

Weight of Coating Class, oz. per sq. ft.	Actual Average Weight of Coating, oz. per sq. ft.	Average Time in Years Required for Appearance of Rust			
		Altoona	Brunot Island	Sandy Hook	State College
0.75	0.88	2.0	2.2	4.8	10.4
1.25	1.30	2.4	3.2	6.8	....
1.50	1.54	3.0	3.5	7.6	....
2.00	2.02	3.8	4.6	10.0	....
2.50	2.58	4.5	5.6	....	....

Perforation of the sheet from the under surface goes ahead while the coating on the exposed surface is still intact. Very early in the history of the Key West test rack, it was evident that the exposed zinc surfaces were becoming covered with an adherent, white, paint-like layer which retarded the deterioration of zinc from that surface. The remarkable preservation of the upper surface distracted the inspection committee's attention from what might be happening on the under side.

When the samples were inspected in March, 1937, it was clear that perforation of the sheets was taking place from the under surface even though the exposed surface was in nearly perfect condition. Evidence of sheet failure was first seen on the exposed surface as small yellow or brown stains through the galvanized coating remaining on the upper side. These evidences of sheet failure were associated generally with the area around the lower purlin. They develop in the part of the corrugation farthest from the purlin; that is, in the crest of the corrugation when considered from above. There does not appear to be any accumulation of debris to which this condition can be laid.

After 10.64 yr. of exposure at Key West, nine specimens showed these spots which indicated an advanced state of deterioration from the under surface. After 11.79 yr., 24 out of a total of 108 galvanized specimens showed this condition.

There seems to be little doubt that the zinc coating failed locally on the under surface near the lower purlin, while the zinc on the upper surface was intact. The time at which local failure of the coating on the under surface took place is unknown. However, from the time required to produce incipient perforation on several of the galvanized sheets, it may be assumed that the protection of the under surface by zinc was appreciable. The 10 uncoated No. 22 gage sheets at this location showed an average time for perforation of 3.8 yr.

Sheet failures in the exposure tests of Committee A-5 have always been considered as having taken place at that inspection when daylight can be seen through a hole or when the bottom edge has fringed $\frac{1}{4}$ in. from the original edge. The kind of sheet failure developing at

TABLE II.—RECORD OF FIRST COATING FAILURES ON CORRUGATED ZINC-COATED SHEETS OF VARIOUS BASE MATERIALS AND VARIOUS WEIGHTS OF COATING AT BRUNOT ISLAND, PA. SHEETS EXPOSED OCTOBER 21, 1926.

Description[a]	Specimen	First Coating Failures, Time in Years												
		Identification of Base Material[b]										All Base Materials		
		R	V	N	T	Y	S	C	K	W	U	Avg.	Min.	Max.
No. 16 gage, 2.50 oz. per sq. ft.	T	5.25	....	....	5.25	4.79	4.27	....	4.79	....	5.50	4.98	4.27	5.50
	B	5.50	....	....	5.78	5.50	5.25	....	5.25	....	5.00	5.38	5.00	5.78
	Average	5.38	....	....	5.52	5.15	4.76	....	5.02	....	5.25	5.18	....	....
No. 22 gage, 2.50 oz. per sq. ft.	T	5.25	4.00	5.25	6.26	4.52	5.25	4.27	5.50	5.50	....	5.09	4.00	6.26
	B	5.78	5.50	5.25	8.53	5.50	7.01	8.53	7.26	6.26	....	6.62	5.25	8.53
	Average	5.52	4.75	5.25	7.40	5.01	6.13	6.40	6.38	5.88	....	5.86	....	....
No. 22 gage, 2.00 oz. per sq. ft.	T	4.27	4.27	4.52	4.00	3.52	4.52	4.00	4.27	4.52	....	4.21	3.52	4.52
	B	4.52	4.79	4.79	4.52	4.52	5.25	4.79	5.78	5.78	....	4.97	4.52	5.78
	Average	4.40	4.53	4.66	4.26	4.02	4.89	4.40	5.03	5.15	....	4.59	....	....
No. 22 gage, 1.50 oz. per sq. ft.	T	3.52	3.25	3.25	3.25	3.52	3.52	3.25	4.00	3.25	....	3.42	3.25	4.00
	B	3.81	3.25	3.81	3.25	3.25	3.81	3.25	4.27	3.25	....	3.55	3.25	4.27
	Average	3.67	3.25	3.53	3.25	3.39	3.67	3.25	4.14	3.25	....	3.49	....	....
No. 22 gage, 1.25 oz. per sq. ft.	T	3.25	3.25	2.53	2.53	3.25	3.25	3.25	3.25	3.25	....	3.09	2.53	3.25
	B	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	....	3.25	3.25	3.25
	Average	3.25	3.25	2.89	2.89	3.25	3.25	3.25	3.25	3.25	....	3.17	....	....
No. 22 gage, 0.75 oz. per sq. ft.	T	....	2.03	2.03	2.27	2.03	2.27	2.27	2.27	....	....	2.17	2.03	2.27
	B	....	2.27	2.03	2.27	2.27	2.27	2.27	2.27	....	....	2.24	2.03	2.27
	Average	....	2.15	2.03	2.27	2.15	2.27	2.27	2.27	....	....	2.21	....	....
No. 28 gage, 0.75 oz. per sq. ft.	T	....	....	2.27	2.03	2.03	2.27	....	2.27	....	....	2.17	2.03	2.27
	B	....	....	2.27	2.27	2.27	2.27	....	2.27	....	....	2.27	2.27	2.27
	Average	....	....	2.27	2.15	2.15	2.27	....	2.27	....	....	2.22	....	....

[a] For deviation in coating weights on individual sheets, see *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 204 (1927).

[b] For approximate composition of base material, see Table V of this report.

TABLE III.—RECORD OF COATING FAILURES ON SANDY HOOK, N. J., TEST RACK.[a] SHEETS EXPOSED MAY 20, 1926.

Description	Number of Specimens in Test	Apr. 24, 1930, 3.93 yr.	Oct. 30, 1930, 4.45 yr.	Apr. 22, 1931, 4.93 yr.	Oct. 21, 1931, 5.42 yr.	Apr. 27, 1932, 5.94 yr.	Oct. 26, 1932, 6.45 yr.	Apr. 26, 1933, 6.93 yr.	Oct. 25, 1933, 7.43 yr.	Oct. 31, 1934, 8.45 yr.	Oct. 30, 1935, 9.45 yr.	Apr. 22, 1936, 9.93 yr.	Oct. 19, 1936, 10.42 yr.	Apr. 28, 1937, 10.95 yr.	Oct. 20, 1937, 11.43 yr.	Total Number of Failures	Average Life in Years
No. 16 gage, 2.50 oz. per sq. ft.	12	none	none	none	none	none	none	none	none	none	none	none	2	3	1	6	....
No. 22 gage, 2.50 oz. per sq. ft.	18	none	none	none	none	none	none	none	none	none	none	none	1	1	5	7	....
No. 22 gage, 2.00 oz. per sq. ft.	18	none	none	none	none	none	none	none	none	4	3	5	2	none	3	17	(9.82)
No. 22 gage, 1.50 oz. per sq. ft.	18	none	none	none	none	none	1	3	9	4	1	..	..	..	..	18	7.63
No. 22 gage, 1.25 oz. per sq. ft.	18	none	none	none	1	3	3	4	7	..	..	..	..	..	..	18	6.80
No. 22 gage, 0.75 oz. per sq. ft.	14	none	10	1	2	none	1	..	..	..	..	..	..	..	..	14	4.77
No. 28 gage, 0.75 oz. per sq. ft.	10	none	6	1	2	none	1	..	..	..	..	..	..	..	..	10	4.89
	108	none	16	2	5	3	6	7	16	8	4	5	5	4	9	..	....
Total failures to date	..	none	16	18	23	26	32	39	55	63	67	72	77	81	90	90	....

[a] Columns representing intermediate inspections at which no new failures were observed have been omitted in this tabulation.

[b] Figures shown in parentheses are not to be considered as final.

Key West on the galvanized specimens does not fit too well with these definitions of failure. The first evidence of approaching failure at Key West is the peculiar yellow or brown stain in the coating of the upper surface over the lower purlin. The stain spreads and may become rough, indicating that rust from the under side has reached the extreme upper surface. The cavity on the lower side is so plugged with a compact, hard filling of rust that daylight does not show through at this stage. Finally, the plug of hard rust cracks or drops out.

TABLE IV.—RECORD OF COATING FAILURES ON STATE COLLEGE, PA., TEST RACK.[a] SHEETS EXPOSED APRIL 23, 1926.

Description	Number of Specimens in Test	Apr. 26, 1932, 6.01 yr.	Oct. 25, 1932, 6.51 yr.	Oct. 29, 1935, 9.52 yr.	Apr. 27, 1936, 10.0 yr.	Oct. 20, 1936, 10.50 yr.	Apr. 27, 1937, 11.0 yr.	Oct. 19, 1937, 11.49 yr.	Total Number of Failures	Average Life in Years
No. 16 gage, 2.50 oz. per sq. ft...	12	none	none	none	none	none	none	none	none	......
No. 22 gage, 2.50 oz. per sq. ft...	18	none	none	none	none	none	none	none	none	......
No. 22 gage, 2.00 oz. per sq. ft...	18	none	none	none	none	none	none	none	none	......
No. 22 gage, 1.50 oz. per sq. ft...	18	none	none	none	none	none	none	none	none	......
No. 22 gage, 1.25 oz. per sq. ft...	18	none	none	none	none	none	none	1	1	......
No. 22 gage, 0.75 oz. per sq. ft...	14	none	1	4	2	4	1	2	14	10.04
No. 28 gage, 0.75 oz. per sq. ft...	10	none	none	1	1	1	1	4	8	(10.87)[b]
	108	none	1	5	3	5	2	7	..	......
Total failures to date..........	...	none	1	6	9	14	16	23	23	......

[a] Columns representing intermediate inspections at which no new failures were observed have been omitted in this tabulation.

[b] Figures shown in parentheses are not to be considered as final.

The inspection committee has not yet decided at just what stage the specimens should be classed as sheet failures and so has not tabulated for this report a decision of which sheets have failed and at what time failure was official.

Sixteen specimens on the east side of the rack show the spots of pending failure, and eight on the west side. Of the ten No. 28 gage specimens, five show this condition. None of the No. 16 gage specimens shows it yet. In the group of No. 22 gage specimens, there are nine spotted ones in the 0.75-oz. coating class, six in the 1.25-oz. coating class, and three in the 1.50-oz. coating class.

The activity of the four northern locations, as indicated by the time required for the appearance of rust on the several samples, is summarized in Table I.

The time at which each individual specimen on the Altoona rack was first found to show rust was given in the 1934 report of the subcommittee.[1] Those data lead the subcommittee to believe that the time at which rust first appeared was a function of the weight and uniformity of the coating rather than of the base material to which the coating was applied. Table II of the present report gives the time at which rust was first found on the specimens at the Brunot Island rack. These data do not alter the earlier indication.

At the Sandy Hook location, there has been an increase in the number of rusty sheets. Table III presents the data from this location. There are eighteen specimens at this location on which rust still has to appear. These are in the 2.00 and 2.50-oz. coating classes.

Table IV shows the number of sheets on which rust has been found at State College. The coatings which have failed are in the lightest coating classes. A considerable amount of time must still elapse before the specimens at this place are as far gone as those at the three other northern locations.

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[1] See Table I, Report of Subcommittee VIII, *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 160 (1934).

The description of weathering at the northern locations given above stated that the zinc wasted away from the upper surface. Figure 1 shows the manner in which the rusted area spreads over the surface of the 0.75-oz. coatings at these locations. In general, these curves are S-shaped. Rust spreads relatively slowly at first and the last traces of zinc are slow to disappear. The wasting of the zinc might be considered as taking place in proportion to time when the rust is spreading between the limits of 20 and 80 per cent of the exposed surface. The rate at which zinc disappears between these limits depends on the severity of the location: the shortest length of time being required at Altoona, the next shortest at Brunot Island, then Sandy Hook, and finally State College.

Although the 0.75-oz. class of coatings are the only ones shown on this graph, this class at Brunot Island behaved very much like the 1.25-oz. class at Altoona. The 0.75-oz. class at Sandy Hook behaved very much like the 2.50-oz. class at Altoona and the 2.00-oz. class at Brunot Island. The 0.75-oz. class at State College is not very different from the 2.00-oz. class at Sandy Hook. While these comparisons are not exact, they serve to show to some extent the relation which exists between weight of coating and location of exposure. Reference to Fig. 2 of the 1934 report will give further illustration of this point.

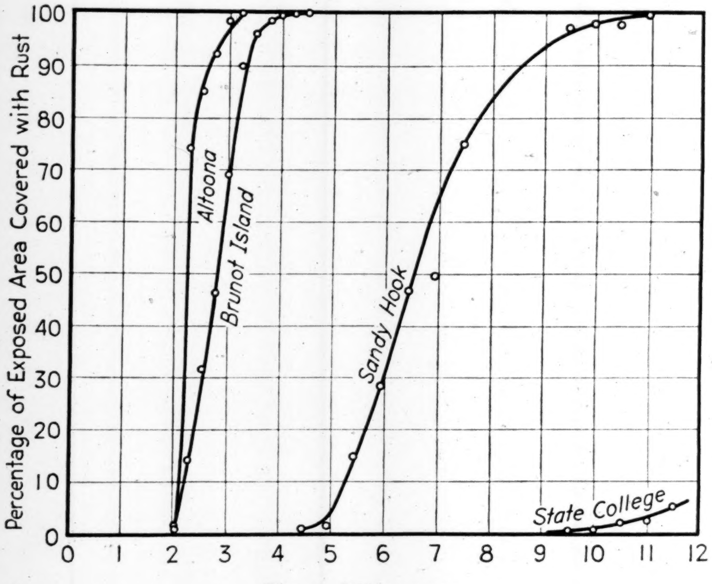

FIG. 1.—Progressive Development of Rust on Specimens of Galvanized Corrugated Sheets Exposed at Four Test Locations.

Uncoated Sheets:

Ten No. 22 gage uncoated sheets were exposed on the rack at each test location along with the galvanized sheets. These sheets have been examined regularly.

Table V shows the time at which the various sheet specimens were found perforated.

Comparison of Tables I and V will show that the relative severity of the five locations on galvanized coatings and on uncoated sheets is quite different. From the performance of coatings, one would place the locations in order of severity as follows: Altoona, Brunot Island, Sandy Hook, State College, and Key West. On the basis of uncoated sheet performance as far as things have advanced now, the locations in order of severity are: Key West, Brunot Island, Sandy Hook, Altoona, and State College.

Coated Hardware, Structural Shapes, Tubular Goods, Etc.:

A special committee on inspection, under the chairmanship of Mr. W. L. Maucher, has continued its inspections of the metallic coated hardware, structural shapes, tubular goods, etc., exposed at Altoona, Brunot Island, Sandy Hook, State College, and Key West. The extensive data given in Table VI show the rusting which has occurred on the samples since the last publication of similar data in the 1935 report.[1]

Few major changes have occurred. The report of this inspection committee is accordingly one of progress.

TABLE V.—TIME IN YEARS FOR PERFORATIONS OF NO. 22 GAGE, BLACK SHEETS.[a]

Identification	Class of Material	Average Chemical Composition									Brunot Island (Pittsburgh), Pa.	Altoona, Pa.	Key West, Fla.	Sandy Hook, N. J.	State College, Pa.
		Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent	Silicon, per cent	Copper, per cent	Nickel, per cent	Chromium, per cent	Molybdenum, per cent					
R	Open-hearth iron	0.011	0.021	0.004	0.018	0.004	0.032	0.023	[d]	0.004[b]	2.03	4.27	3.62	5.94	....
V	Open-hearth iron	0.018	0.053	0.005	0.032	0.004	0.051	0.045	[d]	0.007[b]	2.27	4.27	3.62	4.93	....
U	Open-hearth iron	0.015	0.020	0.004	0.024	0.005	0.087	0.106	[d]	0.009[b]	2.53	4.27	3.62	5.42	....
N	Open-hearth iron	0.013	0.057	0.007	0.029	0.003	0.167	0.057	[d]	0.004[b]	3.00	7.51	3.62	5.94	....
T	Open-hearth iron	0.016	0.157	0.007	0.028	0.004	0.228	0.073	[d]	0.004[b]	9.00	8.52	3.62	6.45	....
Y	Open-hearth steel	0.028	0.346	0.067	0.050	0.005	0.029	0.003[b]	0.013	[c]	2.03	2.03	2.62	3.45	....
S	Open-hearth steel	0.040	0.488	0.072	0.041	0.003	0.051	0.006[b]	0.094	[c]	3.25	9.00	3.62	9.92	....
C	Open-hearth steel	0.066	0.458	0.053	0.045	0.003	0.222	0.003[b]	0.000[b]	[c]	....	X	5.73	10.42	....
K	Open-hearth steel	0.023	0.460	0.066	0.045	0.003	0.268	0.023[b]	0.031	[c]	....	....	4.58	....	....
W	Wrought iron	0.021	0.048	0.143	0.019	0.210	0.025	0.020[b]	[d]	0.003[b]	3.00	5.00	3.62	4.93	....

[a] Blanks in table represent sheets that have not failed as yet. The material has been under observation for approximately 11.5 yr.
[b] Average of determinations in one laboratory.
[c] Less than 0.003 per cent; results of one laboratory.
[d] Less than 0.006 per cent; results of one laboratory.
X Sheet lost due to breaking of straps.

This report of Subcommittee VIII has been submitted to letter ballot of the committee, which consists of 43 members; 33 members returned their ballots, of whom 31 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the subcommittee,

R. F. PASSANO,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, pp. 94 to 103 (1935).

TABLE VI.—REPORT ON INSPECTIONS OF METALLIC COATINGS ON HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC., EXPOSED TO ATMOSPHERE ON TEST RACKS AT FIVE LOCATIONS.

Racks at Five Locations. **Abbreviations and Symbols Used:** 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft. of surface	Exposure at Brunot Island, Pa.					Exposure at Altoona, Pa.						Exposure at State College, Pa.						Exposure at Sandy Hook, N. J.					Exposure at Key West, Fla.	
		329 weeks	356 weeks	379 weeks	407 weeks	459 weeks	330 weeks	357 weeks	382 weeks	408 weeks	434 weeks	460 weeks	329 weeks	356 weeks	381 weeks	407 weeks	433 weeks	459 weeks	330 weeks	357 weeks	408 weeks	434 weeks	460 weeks	305 weeks	404 weeks
3 BY 3 BY $\frac{5}{16}$-IN. PLAIN STEEL ANGLES																									
Electrogalvanized	0.52	80R	Rack down				80R	80R	77R	80R	90R	....	6Ra	<10R	3Ra	5Ra	5Ra	<10R	18R	17R	40R	25Ra	30R	0	0
Hot-dip galvanized	2.52	0					TrY	0	TrY	TrR	slY	....	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum	0.89	0d					0d	0d	0d	0d	0d	....	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated	0.09	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R in 44 weeks						First R in 16 weeks; all R in 304 weeks						First R in 17 weeks; all R in 121 weeks					92R	92R
Electric sherardized	1.38	<10R					<10R	50R 50Y	50R 50Y	....	....	....	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	10Ra	<10R
Lead plated	....	40R*					<10R*	27R	TrY	0d	0d	5R*d	70R*	83R	67R*	70R*	70R*	80R*	53R*	60R	77R*	50R*	60R*	50R	40R
3 BY 3 BY $\frac{5}{16}$-IN. COPPER-BEARING STEEL ANGLES																									
Electrogalvanized	0.37	63R	77R	80R	100R	Missing	88R	90R	90R	90R	95R	97R	3Ra	<10R	3Ra	3Ra	3Ra	5R	13R	13R	23R	25Ra	30Ra	TrR	<10R
Hot-dip galvanized	2.88	0	0	....	....		TrY	0	3Y	slY	slY	slY	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum	0.82	0d	0	0	0d		0d	0	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated	0.24	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R in 69 weeks						57R	65R	60R	67R	70R	70R	First R in 17 weeks; all R in 330 weeks					33R	33R
Electric sherardized	1.44	13R	40R 60Y	20R	20R		40R	57R 43Y	60R 40Y	50R	65R	90R	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	10Ra	<10R
Lead plated	....	<10R*	50R	0d	30R*		<10R*	20R	TrY	0d	0d	<5R*d	63R*	67R	63R*	60R*	60R*	70R*	70R	48R	88R*	80R*	75R*	57R	60R
2 BY $1\frac{1}{2}$ BY $\frac{3}{16}$-IN. PLAIN STEEL ANGLES																									
Electrogalvanized	0.53	First R in 43 weeks; all R in 304 weeks					First R in 44 weeks; all R in 330 weeks						20Ra	40R	33R	30R	30Ra	30Ra	47Ra	53R	70R	60R	60R	<10Ra	<10Ra
Electrogalvanized	0.50	First R in 95 weeks; all R in 277 weeks					First R in 96 weeks; all R in 252 weeks						<5R 3Ra	10R	8R	10R	15Ra	15Ra	70R	65R	80R	90R	85R	<10Ra	10Ra
Hot-dip galvanized	3.24	0	TrY	<5R	TrY	....	TrY	10Y	0	....	10Y	<5Rd	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum	0.75	0d	0d	0d	0d	0d	0d	0	0d	0d	0d	<5Rd	0	0	0	0	0	0	0	0	0	0	0	<10Y	TrR
Cadmium plated	0.43	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 69 weeks						60R	77R	68R	70R	75R	90R	First R in 96 weeks; all R in 330 weeks					53R	60R
Electric sherardized	1.21	First R in 146 weeks; all R in 356 weeks					First R in 96 weeks; all R in 252 weeks						100Y	100Y	10R 90Y	10R* 90Y	100nR	10R 90Y	First R in 96 weeks; all R in 408 weeks					25R 75Y	10R 90nR
Lead plated	....	60R*	53R	....	....	....	<10R*	....	0d	5R*	0d	<5Rd	47R*	63R	55R	47R*	57R*	65R*	53R*	70R*	43R*	30R*	60R*	<10R 20Y	18R
2 BY $1\frac{1}{2}$ BY $\frac{3}{16}$-IN. COPPER-BEARING STEEL ANGLES																									
Electrogalvanized	0.70	First R in 43 weeks; all R in 379 weeks					First R in 44 weeks; all R in 460 weeks						10Ra	15R	15R	15R	20R	30Ra	30R	40R	50R	50Ra	60R	<10Ra	<10Ra
Electrogalvanized	0.76	First R in 43 weeks; all R in 379 weeks					First R in 17 weeks; all R in 460 weeks						10Ra	15R	13R	13R	20Ra	17R	40R	32R	55R	50Ra	50R	<10Ra	12Ra
Hot-dip galvanized	2.75	0	2Y	<5R	TrY	20R	TrR	10Y	TrY	<2R	TrR	<5R	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum	0.50	0d	....	0d	0d	0d	0d	0	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	<10Y	0
Cadmium plated	0.50	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 69 weeks						47R	73R	77R	70R	75R	80R	First R in 44 weeks; all R in 382 weeks					38R	53R
Electric sherardized	1.15	First R in 95 weeks; all R in 329 weeks					First R in 120 weeks; all R in 252 weeks						First R in 43 weeks; all R in 356 weeks						First R in 147 weeks; all R in 408 weeks					All R in 52 weeks	
Gas sherardized	**0.17**	**First R in 16 weeks; all R in 68 weeks**					First R in 17 weeks; all R in 44 weeks						....	....	....	....	....	....	**First R in 44 weeks; all R in 44 weeks**					**All R in 52 weeks**	
Lead plated	....	33R*	40R	80R*	10R*	10R*	0d	....	....	5R*d	0d	0d	50R*	73R*	63R*	60R*	50R*	85R*	20R*	48R	33R*	30R*	60R*	13R	40R

Lead plated....	....	33R*	40R	80R*	10R*	10R*	0d	....	....	5R*d	0d	0d	50R*	73R*	63R*	60R*	50R*	85R*	20R*	48R	33R*	30R*	60R*	52 weeks 13R	40R

2-in. Diameter Tubular Goods

Electrogalvanized.	1.58	20R	39R	73R	80R	90R	0	5R	63R	70R	90R	95R	0	0	0	0	0	0	0	Missing				0	0
Hot-dip galvanized.	2.51	10Y	20Y	<10Y	<10Y	<10Y	<10R 41Y	7R 50Y	3R 43Y	3R	5R 67Y	90R	0	0	0	0	0	0	0	Missing				0	0
Hot-dip Aluminum.	4.73	0d	0d	0	0d	0	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	Missing			Rack down	<10R	<10R
Cadmium plated...	0.23	First R in 16 weeks; all R in 95 weeks					First R in 17 weeks; all R in 69 weeks						50R	57R	60R	73R	70R	.70R	First R in 44 weeks; all R in 330 weeks					<10R	17R
Cadmium plated...	0.10	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 69 weeks						67R	78R	70R	87R	87R	80R	First R in 44 weeks; all R in 278 weeks					53R	80R
Electric sherardized.	0.29	First R in 43 weeks; all R in 120 weeks					First R in 44 weeks; all R in 121 weeks						76R	82R 17Y	95R	93R	95R	95R	First R in 96 weeks; all R in 252 weeks					25R 75Y	75R
Electric sherardized.	0.85	First R in 43 weeks; all R in 120 weeks					First R in 44 weeks; all R in 121 weeks						75R	77R 23Y	95R	95R	99R	99R	First R in 96 weeks; all R in 226 weeks					<10R 90Y	100nR
Gas sherardized....	0.66	47R	62R	70R	70R	75R	75R	80R	80R	80R	90R	90R	0d	0d	0d	0d	0d	0d	100Y	TrR 100Y	<Re Y	TrR		<10R 85Y	100nR
Lead plated.......	....	30R	17R	20R*	30R*	30R*	0d	0d	0d	0d	0d	>5Rd*	First R in 16 weeks: all R in 459 weeks						50R*	67R	70R*	50R*		20R	53R

1-in. Diameter Tubular Goods

Electrogalvanized..	1.62	0	5Y	0	2R	37R	TrY	8R	30R 33d	37R	62R	82R												0	0
Hot-dip galvanized.	1.83	100Y	100Y	100Y	50R	85R	40R	65R 35Y	68R 32Y	87R	95R	100R	Rack Damaged						Rack Damaged					0	0
Hot-dip aluminum..	1.83	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	Specimens Mixed						Specimens Mixed					TrR	TrR
Cadmium plated...	0.30	First R in 16 weeks; all R in 95 weeks					First R in 17 weeks; all R in 96 weeks																	85R	90R
Cadmium plated...	1.18	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R in 96 weeks																	0	TrR
Electric sherardized.	0.42	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R in 120 weeks																	83R 17Y	93R
Electric sherardized.	0.92	First R in 146 weeks; all R in 356 weeks					75R	83R 17Y	70R	70R	70R	80R												50Y	100nR
Gas sherardized....	0.72	57R	92R	90R	90R	90R	75R	77R 23Y	70R	70R	70R	80R												100Y	100nR
Calorized.........	....	0d	0d	0d	0d	0d	0d	100Y	0d	0d	0d	<5R*												10R 50Y	40R
Lead plated.......	....	30R*	13R	20R*	15R*	30R*	0d	0d	0d	0d	0d	<5R*												10R	37R
Amaloy...........	....	70R*	37R*	20R*	60R*	30R*	0d	0d	0d	0d	0d	<5R*d												<10R	30R

Forged Steel Tower Fittings

Electrogalvanized. Bolt	0.31	First R in 95 weeks; all R in 379 weeks					First R in 69 weeks; all R in 357 weeks						0	0	0	0	0	0	<10R	<10R	20R	30R	30R	<10R	<10R
Nut	0.54																								
Clamp	1.15																								
Electrogalvanized. Bolt	0.02	84R	89R	90R	90R	93R	First R in 69 weeks; all R in 357 weeks						<10R	<10R	<10R	<10R	<10R	10R	17R	27R	43R	60R	65R	0	0
Nut	0.01																								
Clamp	0.46																								
Hot-dip galvanized.	2.67	TrR 40Y	23R 40Y	20R	20R	20R	20R 80Y	....	20R	25R 75Y	30R 70Y	30R	0	0	0	0	0	0	0	0	0	0	15Y	10R	13R
Hot-dip galvanized.	1.53	43R	82R 18Y	60R	87R	97R	40R 60Y	75R	73R	70R	85R	90R	TrY	0	0	TrY	0	0	0	0	0	50Y	85Y	slY	0
Hot-dip aluminum..	....	0	0	0	0d	0d	0d	0d	0d	0d	0d	<5R	0	0	0	0	0	0	0	0	0	0	25Y	<10R 20Y	60R 40Y
Cadmium plated....	0.40	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R in 121 weeks						10R	10R	10R	10R	10R	10R	First R in 44 weeks; all R in 252 weeks					20R	20R
Electric sherardized.	0.50	10R	17R 50Y	20R	60R	70R	30R 33Y	33R 67Y	32R 30Y	37R	50R	67R	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	50Y	100Y
Gas sherardized....	....	First R in 95 weeks; all R in 379 weeks					First R in 147 weeks; all R in 434 weeks						100Y	33R 67Y	20R 80YnR	43R	5R 95nR	50R	First R in 330 weeks; all R in 460 weeks					93Y	100nR
Parkerized.........	....	First R in 16 weeks; all R in 304 weeks					First R in 121 weeks; all R in 434 weeks						First R in 43 weeks; all R in 199 weeks						First R in 17 weeks; all R in 305 weeks					All R in 52 weeks	
Cadmium plated....	0.26	First R in 16 weeks; all R in 146 weeks					First R in 17 weeks; all R in 69 weeks						60R	83R	85R	80R	80R	90R	70R	83R	90R	90R	95R	24R	80R
Lead plated........	....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						All R in 16 weeks						All R in 17 weeks					All R in 52 weeks	

TABLE VI.—REPORT ON INSPECTIONS OF METALLIC COATINGS ON HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC. (*Continued*).

Racks at Five Locations. Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft., of surface	Exposure at Brunot Island, Pa.					Exposure at Altoona, Pa.						Exposure at State College, Pa.						Exposure at Sandy Hook, N. J.					Exposure at Key West, Fla.	
		329 weeks	356 weeks	379 weeks	407 weeks	459 weeks	330 weeks	357 weeks	382 weeks	408 weeks	434 weeks	460 weeks	329 weeks	356 weeks	381 weeks	407 weeks	433 weeks	459 weeks	330 weeks	357 weeks	408 weeks	434 weeks	460 weeks	305 weeks	404 weeks
$\frac{3}{4}$-in. Nipples and Ells																									
Electrogalvanized MI Nipple Ell	1.64 1.55	10R	22R	30R	20R	70R	15R	23R	33R	40R	60R	70R	0	0	0	0	0	0	0	0	0	TrR	5R	0	0
Electrogalvanized CI Nipple Ell	2.02 2.36	0	0	<10R	TrR	25R	0	0 slY	0	<1R	10R	10R	0	0	0	0	0	0	0	0	0	TrR	3R	0	0
Electrogalvanized MI Nipple Ell	2.43 2.90	70R	73R 20Y	50R	80R	100R	83R	87R	83R	83R	87R	100R	TrR	TrR	TrR	TrR	TrR	TrR	15R	17R 1Y	17R	33R	30R	slR	<10R
Electrogalvanized CI Nipple Ell	1.82 0.67	53R	57R 23Y	....	65R	77R	53R	....	62R 25Y	65R	77R	73R	TrR	TrR	TrR	TrR	TrR	TrR	<10R	12R 3Y	67R	63R	60R	<10R	<10R
Hot-dip galvanized MI........	1.82	<10R 90Y	7R 70Y	20R	25R	70R	<10R 90Y	....	<10R 90Y	10R 90Y	25R	70R	0	0	0	0	0	0	0	0	0	slY	100Y	0	0
Hot-dip galvanized CI.........	1.44	17R	23R 35Y	20R	45R	....	43R	....	40R 60Y	50R	60R	90R	0	0	0	0	0	0	0	0	0	slY	100Y	0	TrR
Hot-dip aluminum MI.........	3.20	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	<5R	TrRth	Rth	Rth	Rth	Rth	Rth	Rth	Rth	<10R	Rth	50YRth	12R	25R
Hot-dip aluminum CI..........	2.80	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	<5R	TrRth	Rth	Rth	Rth	Rth	Rth	Rth	Rth	<10R	Rth	50YRth	42R	30R
Cadmium plated MI	....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 69 weeks						80R	92R	90R	95R	80R*	95R	First R in 96 weeks; all R in 174 weeks					30R	75R
Cadmium plated CI.	....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 146 weeks; all R in 407 weeks						First R in 96 weeks; all R in 147 weeks					<10R 90Y	80R
Cadmium plated MI	....	First R in 146 weeks; all R in 356 weeks					First R in 17 weeks; all R in 69 weeks						80R	83R	90R	98R	90R*	95R	First R in 96 weeks; all R in 147 weeks					90Y	77R
Cadmium plated CI.	....	First R in 146 weeks; all R in 356 weeks					First R in 17 weeks; all R in 44 weeks						First R in 146 weeks; all R in 433 weeks						First R in 96 weeks; all R in 121 weeks					75R	87R
Electric sherardized MI......	0.63	First R in 120 weeks; all R in 379 weeks					First R in 147 weeks; all R in 330 weeks						100Y	100Y	100Y	100Y	100Y	100Y	First R in 330 weeks; all R in 408 weeks					100Y	<10R 90Y
Electric sherardized CI.......	0.47	First R in 95 weeks; all R in 251 weeks					First R in 147 weeks; all R in 357 weeks						100Y TrR	13R 87Y	30R 70Y	17R	....	50R	First R in 330 weeks; all R in 408 weeks					100Y	5R 95Y
Gas sherardized MI	0.78	First R in 120 weeks; all R in 356 weeks					First R in 96 weeks; all R in 382 weeks						100Y	47R 53Y	40R 60Y	40R	40R Y	50R	First R in 52 weeks; all R in 357 weeks					First R in 52 weeks; all R in 305 weeks	
Gas sherardized CI.	0.84	First R in 120 weeks; all R in 356 weeks					First R in 96 weeks; all R in 330 weeks						40R	47R 53Y	50R 50Y	45R	50R	60R	First R in 52 weeks; all R in 357 weeks					75Y	67R 33Y
Parkerized MI.....	....	<10R <10Y	20R 43Y	30R	30R	70R	60R	82R	77R	90R	....	100R	First R in 43 weeks; all R* in 356 weeks						First R in 69 weeks; all R* in 330 weeks					First R in 52 weeks; all R in 162 weeks	
Parkerized CI......	....	25R	40R 27Y	40R	40R	70R	50R	50R	55R	55R	60R	80R*	First R in 43 weeks; all R* in 356 weeks						First R in 69 weeks; all R* in 330 weeks					First R in 52 weeks; all R in 162 weeks	
Electric sherardized MI.........	0.75	20R	27R 50Y	30R*	20R	60R	40R	62R	40R	43R	75R	80R*	TrY	100Y	100Y	100Y	100Y	100Y	100Y	100Y	1R	TrR 100Y	<10R 90Y	....	100Y
Electric sherardized CI..........	0.82	30R	33R 30Y	30R*	20R	40R	30R	62R	50R	40R	75R	80R	100Y	27R 73Y	20R 80Y	13R Y	100Y	40R	100Y	1R 99Y	3R	TrR 100Y	10R 90Y	....	77R
Amaloy MI........	....	....	....	....	....	....	0d	0d	0d	0d	0d	<5R	First R in 16 weeks; all R* in 356 weeks						First R in 17 weeks; all R* in 460 weeks					....	60R
Amaloy CI........	....	....	....	....	....	....	0d	0d	0d	0d	0d	<5R	First R in 16 weeks; all R* in 433 weeks						First R in 17 weeks; all R* in 460 weeks					....	....

MI indicates malleable iron base metal.
CI indicates cast iron base metal.

TOWER CLAMPS

Electrogalvanized MI	Bolt	0.31	First R in 68 weeks; all R in 459 weeks					First R in 96 weeks; all R in 460 weeks						0	0	0	0	0	0	15R	25R 3Y	33R	40R	40R	<10R	<10R
	Nut	0.54																								
	Clamp	1.15																								
Electrogalvanized CI	Bolt	0.28	First R in 95 weeks; all R in 407 weeks					First R in 96 weeks; all R in 305 weeks						0	0	0	0	0	0	30R	45R	80R	80R	80R	0	0
	Nut	0.56																								
Electrogalvanized MI	Bolt	0.02	First R in 68 weeks; all R in 356 weeks					First R in 17 weeks; all R in 200 weeks						12R	30R	27R	27R	32R	30R	47R	54R	58R	50R	75R	20R	20R
	Nut	0.01																								
	Clamp	0.46																								
Electrogalvanized CI	Bolt	0.04	First R in 95 weeks; all R in 356 weeks					First R in 17 weeks; all R in 200 weeks						13R	37R	33R	37R	45R	50R	75R	65R	75R	65R	90R	48R	47R
	Nut	0.04																								
	Clamp	0.74																								
Hot-dip galvanized MI........		1.53	10R	43R 57Y	80R	70R	90R	First R in 330 weeks; all R in 460 weeks						0	0	0	0	0	0	0	0	0	0	slY	<10Y	TrR
Hot-dip galvanized CI..........		1.75	10R	40R 60Y	40R	50R	70R	First R in 330 weeks; all R in 460 weeks						0	0	0	0	0	0	0	0	0	0	slY	0	0
Hot-dip galvanized MI........		2.00	10Y	12R 13Y	<10R	<10R	10R	50Y	13R 50Y	<10R	<10R	<10R	20R	0	0	0	0	0	0	0	0	0	0	slY	0	0
Hot-dip galvanized CI.........		2.38	<10R	8R 13Y	<10R	<10R	10R	50Y	....	....	<10R	<10R	55R	0	0	0	0	0	0	0	0	0	0	slY	0	0
Cadmium plated MI		0.28	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 69 weeks						First R in 95 weeks; all R in 381 weeks						First R in 44 weeks; all R in 147 weeks					33R	67R
Cadmium plated CI		0.28	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 69 weeks						First R in 146 weeks; all R in 356 weeks						First R in 44 weeks; all R in 121 weeks					57R	80R
Cadmium Plated MI		0.15	All R in 16 weeks					First R in 17 weeks; all R in 69 weeks						First R in 16 weeks; all R in 173 weeks						First R in 17 weeks; all R in 69 weeks					First R in 52 weeks; all R in 162 weeks	
Cadmium plated CI.		0.17	All R in 16 weeks					First R in 17 weeks; all R in 69 weeks						First R in 16 weeks; all R in 173 weeks						First R in 17 weeks; all R in 69 weeks					First R in 52 weeks; all R in 162 weeks	
Electric sherardized MI		....	First R in 16 weeks; all R in 68 weeks					First R in 44 weeks; all R in 278 weeks						First R in 16 weeks; all R in 433 weeks						First R in 17 weeks; all R in 69 weeks					All R in 52 weeks	
Electric sherardized CI..........		1.82	First R in 225 weeks; all R in 329 weeks					First R in 199 weeks; all R in 382 weeks						100Y	100Y	100Y	100Y	100Y	100nR	First R in 96 weeks; all R in 408 weeks					17R 73Y	20R 80Y
Gas sherardized MI.		0.50	First R in 95 weeks; all R in 251 weeks					First R in 120 weeks; all R in 408 weeks						100Y	100Y	100nR	80nR	100nR	100nR	First R in 174 weeks; all R in 226 weeks					<10R 57Y	100Y
Gas sherardized CI.		0.63	First R in 120 weeks; all R in 329 weeks					First R in 120 weeks; all R in 382 weeks						30R 70Y	90R	90R 10Y	90R	80R	100R	First R in 52 weeks; all R in 408 weeks					First R in 52 weeks; all R in 162 weeks	
Parkerized MI.....		....	First R in 43 weeks; all R in 143 weeks					First R in 44 weeks; all R* in 357 weeks						First R in 16 weeks; all R* on 329 weeks						First R in 44 weeks; all R* in 44 weeks					All R in 52 weeks	
Parkerized CI......		....	First R in 43 weeks; all R in 459 weeks					First R in 44 weeks; all R* in 460 weeks						First R in 43 weeks; all R* in 329 weeks						First R in 44 weeks; all R* in 305 weeks					All R in 52 weeks	
Hot-dip aluminum MI........		3.16	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	<10R	0	0	0	0	0	0	0	0	0	0	0	<10R	10R
Hot-dip aluminum CI........		2.51	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	<10R	0	0	0	0	0	0	0	0d	0	0	0d	<10R	10R
Amaloy MI........		....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R* in 121 weeks						First R in 16 weeks; all R* in 329 weeks						First R in 17 weeks; all R* in 17 weeks					First R in 52 weeks; all R in 102 weeks	
Amaloy CI........		....	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R* in 330 weeks						First R in 16 weeks; all R* in 329 weeks						First R in 17 weeks; all R* in 305 weeks					First R in 52 weeks; all R in 162 weeks	

MI—indicates malleable iron base metal.
CI—indicates cast iron base metal.

TABLE VI.—REPORT ON INSPECTIONS OF METALLIC COATINGS ON HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC. (*Continued*).

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Coating	Weight, oz. per sq. ft., of surface	Exposure at Brunot Island, Pa.					Exposure at Altoona, Pa.						Exposure at State College, Pa.						Exposure at Sandy Hook, N. J.					Exposure at Key West, Fla.	
		329 weeks	356 weeks	379 weeks	407 weeks	459 weeks	330 weeks	357 weeks	382 weeks	408 weeks	434 weeks	460 weeks	329 weeks	356 weeks	381 weeks	407 weeks	433 weeks	459 weeks	330 weeks	357 weeks	408 weeks	434 weeks	460 weeks	305 weeks	404 weeks
1½ by 1½ by ⅛-in. Plain Steel Angles																									
Electrogalvanized..	0.47	First R in 68 weeks; all R in 379 weeks					First R in 96 weeks; all R in 434 weeks						20R	20R	20Ra	25Ra	20Ra	25Ra	30Ra	38R	50R	60R	40R	<10Ra	<10Ra
Electrogalvanized..	1.09	First R in 146 weeks; all R in 379 weeks					First R in 69 weeks; all R in 408 weeks						0	0	0	0	0	0	20R	22R	47	57R	30R	TrY	0
Hot-dip galvanized.	3.16	0	1Y	<10R	<10R	<10R	<10R	1R 43Y	7R 3Y	<5R	7R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum..	0.89	0d	0d	0d	0d	0d	0d	0	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	TrY	0
Cadmium plated...	0.12	First R in 95 weeks; all R in 199 weeks					First R in 17 weeks; all R in 69 weeks						50R	70R	65R	67R	67R	70R	First R in 17 weeks; all R in 226 weeks					22R	30R
Electric sherardized.	0.14	First R in 43 weeks; all R in 68 weeks					First R in 96 weeks; all R in 330 weeks						40R	42R 58Y	47R 53Y	40R	42R	57R	First R in 147 weeks; all R in 408 weeks					<10R 90Y	100nR
Gas Sherardized....	....	First R in 16 weeks; all R in 225 weeks					First R in 17 weeks; all R in 69 weeks						First R in 43 weeks; all R in 146 weeks						First R in 44 weeks; all R in 96 weeks					First R in 52 weeks; all R in 162 weeks	
Lead plated........	....	10R*	10R*	<10R*	10R*	30R*	<10R*	73R	100Y	TrRd	0d	5R*d	30R*	62R	27R*	30R*	40R*	50R*	33R*	32R*	30R*	30R*	50R	12R 25Y	40R
1½ by 1½ by ⅛-in. Copper Bearing Steel Angles																									
Electrogalvanized..	0.76	First R in 43 weeks; all R in 379 weeks					First R in 44 weeks; all R in 278 weeks						7R*	12R	8Ra	7R	10Ra	25Ra	43Ra	43R	60R	60R	40R	0	0
Electrogalvanized..	0.47	First R in 120 weeks; all R in 277 weeks					First R in 96 weeks; all R in 278 weeks						7R*	5R 3Y	TrR 5Ra	13R TrY	18R	27R 3Ra	17R	42R	30R	80R	75R	0	TrR
Hot-dip galvanized.	3.20	0	TrY	0	0	TrY	<10Y	2R 50Y	TrR <10Y	TrR	TrR 7Y	5R	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum..	1.11	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	<10Y	TrR
Cadmium plated...	0.65	First R in 146 weeks; all R in 277 weeks					First R in 17 weeks; all R in 96 weeks						47R	53R	55R	60R	60R	60R	First R in 17 weeks; all R in 408 weeks					12Ra	15Ra
Electric sherardized.	....	....	....	....	....	....	First R in 147 weeks; all R in 330 weeks						100Y	100Y	<10R 90Y	TrR Y	TrR 99Y	10R 90Y	First R in 121 weeks; all R in 408 weeks					<10R 93Y	100nR
Gas sherardized....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lead plated........	....	....	20R	10R*	10R*	30R*	0d	....	0d	0d	0d	10R*d	60R*	60R*	63R*	....	60R*	80R*	35R*	32R*	47R*	47R*	35R*	13R	30R
No. 14 by 2½-in. Plain Steel Flats																									
Electrogalvanized..	0.45	First R in 68 weeks; all R in 199 weeks					First R in 96 weeks; all R in 200 weeks						0	0	0	0	0	0	First R in 147 weeks; all R in 434 weeks					0	TrR
Electrogalvanized..	0.70	73R	86R	90R	87R	95R	60R	82R 18Y	73R	85R Y	90R	99R	0	0	0	0	0	0	0	0	0	0	TrR	0	0
Hot-dip galvanized.	3.16	TrR	2R 3Y	<10R	5R	90R	20Y	1R 18Y	<10R	<10R d	5R	80R	0	0	0	0	0	0	0	0	0	0	TrY	0	0
Hot-dip aluminum..	0.89	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated...	....	First R in 43 weeks; all R in 68 weeks					First R in 17 weeks; all R in 44 weeks						27R	30R	31R	40R	42R	55R	First R in 69 weeks; all R in 200 weeks					15R	17R
Electric sherardized.	0.58	First R in 43 weeks; all R in 199 weeks					First R in 44 weeks; all R in 226 weeks						<10R 95Y	7R 93Y	<10R 90Y	<10R	5R 95Y	5R 95Y	First R in 147 weeks; all R in 305 weeks					10R 90Y	10R 90Y
Gas sherardized....	....	First R in 146 weeks; all R in 225 weeks					First R in 147 weeks; all R in 330 weeks						TrR 100Y	4R 96Y	<10R 90Y	<10R	5R 95Y	15R 85Y	73R	10R 78R	77R	83R	80R	<10R 95Y	<10R 80nR
Lead plated.......	....	10R*	13R	<10R	10R*	20R*	0d	....	0d	0d	0d	5R	10R*	27R	15R	15R*	20R*	30R*	20R*	35R	30R*	25R*	50R*	13R	13R

No. 14 by 2½-in. Copper Bearing Steel Flats

Electrogalvanized	0.29	First R in 68 weeks; all R in 199 weeks					First R in 44 weeks; all R in 147 weeks						0	0	0	0	0	0	98R	98R	98R	95R	98R	0	TrR
Electrogalvanized	0.62	70R	72R	80R	80R	83R	First R in 147 weeks; all R in 278 weeks						0	0	0	0	0	0	0	1Y	3R	5R	20R	<10R	<10R
Hot-dip galvanized	3.20	TrR	1R 2Y	13R	5R	13R	10Y	2R 10Y	<10R	<10R	<10R	10R	0	0	0	0	0	0	0	0	0	0	TrY	0	0
Hot-dip aluminum	0.47	0d	0	0	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated	....	First R in 16 weeks; all R in 68 weeks					First R in 44 weeks; all R in 69 weeks						<10R	15R	10R 17Y	55R	63R	77R	First R in 17 weeks; all R in 278 weeks					63R	85R
Electric sherardized	....	First R in 16 weeks; all R in 225 weeks					First R in 44 weeks; all R in 174 weeks						<10R 90Y	12R 88Y	13R 87Y	10R	10R 90Y	10R 90Y	First R in 17 weeks; all R in 305 weeks					<10R 92Y	<10R 95nR
Gas sherardized	....	First R in 146 weeks; all R in 356 weeks					First R in 121 weeks; all R in 357 weeks						100Y	100Y	100Y	100Y	100Y	100Y	77R	80R 20Y	83R 17Y	83R	80R 20Y	<10R 95Y	<10R 95nR
Lead plated	....	10R*	8R	<10R	10R*	20R*	0d	....	0d	0d	0d	<5Rd	10R*	37R	20R	20R*	15R*	40R*	20R*	30R	20R*	20R*	40R*	12R	12R

¼ by 6-in. Bolts

Sherardized	1.10	17R	29R	33R	36R	67R	37R	53R	47R	75R	87R	100R	100Y	100Y	100Y	100Y	100Y	25R	First R in 99 weeks; all R in 226 weeks					First R in 52 weeks; all R in 305 weeks	
Sherardized	0.68	First R in 173 weeks; all R in 459 weeks					First R in 252 weeks; all R in 382 weeks						0	100slY	0	0	0	0	100Y	100Y	100Y	100Y	75R 25Y	10Y	100Y
Hot-dip galvanized	1.61	First R in 329 weeks; all R in 379 weeks					First R in 226 weeks; all R in 357 weeks						0	0	0	0	0	0	0	0	0	0	TrY	0	TrR
Electrogalvanized	0.33	First R in 16 weeks; all R in 95 weeks					First R in 17 weeks; all R in 96 weeks						33R	65R	67R	70R	73R	99R	First R in 44 weeks; all R in 226 weeks					90R	95R
Cadmium plated	0.29	All R in 16 weeks					First R in 44 weeks; all R in 69 weeks						First R in 16 weeks; all R in 199 weeks						First R in 121 weeks; all R in 226 weeks					First R in 52 weeks; all R in 206 weeks	
Cadmium plated	0.22	First R in 68 weeks; all R in 95 weeks					First R in 17 weeks; all R in 44 weeks						6R	7R TrY	7R	5R	2R	30R	First R in 17 weeks; all R in 69 weeks					0	0

⅝ by 2½-in. Bolts

Sherardized	0.87	25R	43R	20R	40R	90R	55R	87R	80R	90R	97R	100R	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	5R 95Y	28Y	75Y
Sherardized	0.70	<10R	20R	5R	25R	90R	3R	4R	10R	15R	40R	80R	100Y	100Y	100Y	100Y	100Y	100Y	60R	72R	97R	100R	100R	50R 50Y	100R
Hot-dip galvanized	1.40	0Y	1R 50Y	1R 80Y	10R	90R	3R 33Y	23R	10R 40Y	30R	70R	90R	0	0	0	0	0	0Y	0	0	0	0	TrY	0	0
Cadmium plated	....	First R in 43 weeks; all R in 95 weeks					First R in 44 weeks; all R in 69 weeks						3R	12R	15R	20R	20R	50R	First R in 17 weeks; all R in 226 weeks					0	0
Cadmium plated	....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 16 weeks; all R in 120 weeks						First R in 17 weeks; all R in 44 weeks					First R in 52 weeks; all R in 263 weeks	
Electrogalvanized	0.20	First R in 43 weeks; all R in 95 weeks					First R in 17 weeks; all R in 69 weeks						61R	65R	68R	63R	70R	60R	First R in 69 weeks; all R in 252 weeks					60R	80R

½ by 2½-in. Bolts

Sherardized	0.84	10R	30R	30R	40R	90R	40R	57R	80R	95R	97R	100R	0d	100Y	100Y	100Y	100Y	100Y	100Y	100Y	5R	4R Y	25R 75Y	10Y	50Y
Sherardized	0.79	TrR	1R 33Y	TrR	5R	30R	TrR	3R	3R	5R	10R	70R	100Y	100Y	100Y	100Y	100Y	100Y	First R in 226 weeks; all R in 434 weeks					20R 80Y	100nR
Hot-dip galvanized	1.48	0Y	6R 37Y	3R 67R	10R	80R	TrR 100Y	....	18R	25R	30R	90R	0	0	0	0	0	0	0	0	0	0	TrY	0	0
Electrogalvanized	0.21	First R in 68 weeks; all R in 95 weeks					First R in 17 weeks; all R in 69 weeks						47R	65R	80R	90R	90R	90R	First R in 96 weeks; all R in 252 weeks					83R	80R
Electrogalvanized	0.20	First R in 43 weeks; all R in 68 weeks					First R in 17 weeks; all R in 44 weeks						<10R	20R	18R	23R	20R	90R	First R in 69 weeks; all R in 174 weeks					<10R	10R
Cadmium plated	0.30	All R in 16 weeks					All R in 17 weeks						First R in 16 weeks; all R in 120 weeks						First R in 17 weeks; all R in 69 weeks					First R in 52 weeks; all R in 206 weeks	

TABLE VI.—REPORT ON INSPECTIONS OF METALLIC COATINGS ON HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC. (*Continued*).

Racks at Five Locations. Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft., of surface	Exposure at Brunot Island, Pa.					Exposure at Altoona, Pa.						Exposure at State College, Pa.						Exposure at Sandy Hook, N. J.					Exposure at Key West, Fla.	
		329 weeks	356 weeks	379 weeks	407 weeks	459 weeks	330 weeks	357 weeks	382 weeks	408 weeks	434 weeks	460 weeks	329 weeks	356 weeks	381 weeks	407 weeks	433 weeks	459 weeks	330 weeks	357 weeks	408 weeks	434 weeks	460 weeks	305 weeks	404 weeks
$\frac{3}{8}$ BY 1½-IN. BOLTS																									
Sherardized........	1.20	0	2R	....	2R	10R	0d	0d	0d	0d	0d	3R	100Y	100Y	50Y	100Y	100Y	100Y	100Y	100Y	TrR	TrR 99Y	10R 90Y	50R 50Y	90R
Sherardized........	0.89	<10R	18R	10R	25R	90R	20R	40R	50R	70R	75R	90R	0	100Y	....	100Y	100Y	100Y	30R	53R	70R	53R	100R	10Y	100Y
Hot-dip galvanized.	1.45	0Y	10R 15Y	100Y	20R	90R	20R	70R	50R	50R	50R	90R	0	0	0	0	0	0	0	0	0	0	TrY	0	0
Electrogalvanized..	0.18	100R	First R in 43 weeks; all R in 95 weeks				First R in 44 weeks; all R in 96 weeks						73R	90R	90R	90R	95R	95R	First R in 44 weeks; all R in 200 weeks					First R in 102 weeks; all R in 305 weeks	
Cadmium plated....	0.14	100R	First R in 16 weeks; all R in 68 weeks				First R in 17 weeks; all R in 44 weeks						37R	63R	63R	80R	90R	90R	First R in 76 weeks; all R in 226 weeks					12R	50R 50Y
Cadmium plated....	0.15	100R	First R in 16 weeks; all R in 43 weeks				All R in 17 weeks						First R in 63 weeks; all R in 199 weeks						First R in 17 weeks; all R in 69 weeks					First R in 102 weeks; all R in 305 weeks	
1-IN. ROOFING NAILS																									
Sherardized........	0.90	First R in 146 weeks; all R in 225 weeks					First R in 200 weeks; all R in 252 weeks						100Y	10R	50R	1R 99Y	100Y	20R	First R in 226 weeks; all R in 330 weeks					50R 50Y	100R
Sherardized........	0.86	First R in 146 weeks; all R in 225 weeks					First R in 200 weeks; all R in 252 weeks						100Y	10R	50Y	100Y	100Y	<10R	First R in 252 weeks; all R in 408 weeks					50R 50Y	100R
Cadmium plated...	....	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 44 weeks						10R	30R	50R	75R	60R	100R	First R in 69 weeks; all R in 147 weeks					50R	100R
Hot-dip galvanized.	1.34	First R in 173 weeks; all R in 277 weeks					First R in 147 weeks; all R in 226 weeks						0	0	0	0	0	0	0	0	0	0	....	0	0
Hot-dip galvanized.	1.15	First R in 173 weeks; all R in 251 weeks					First R in 147 weeks; all R in 226 weeks						0	0	0	0	0	0	0	0	0	0	....	0	0
Electrogalvanized..	....	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 121 weeks						80R	90R	90R	....	90R	100R	First R in 17 weeks; all R in 330 weeks					First R in 52 weeks; all R in 404 weeks	
Amaloy...........	....	20R	50R 50Y				0d	0d	0d	0d	0d	0d	First R in 16 weeks; all R in 381 weeks						100R*	60R	100R	20R 80Y	90R	First R in 52 weeks; all R in 263 weeks	
NO. 14 BY 2½-IN. WOOD SCREWS																									
Sherardized........	0.94	First R in 68 weeks; all R in 304 weeks					First R in 121 weeks; all R in 330 weeks						<10R	10R 90Y	<10R 50Y	10R	10R	25R	First R in 147 weeks; all R in 357 weeks					0	10R 90Y
Sherardized........	0.86	First R in 68 weeks; all R in 356 weeks					First R in 147 weeks; all R in 330 weeks						<10R	1R 99Y	TrR	TrR	5R	<5R	First R in 226 weeks; all R in 408 weeks					....	5R 95Y
Cadmium plated...	0 07	First R in 16 weeks; all R in 43 weeks					First R in — weeks; all R in 17 weeks						<10R	10R	10R	10R	10R	10R	First R in 121 weeks; all R in 408 weeks					....	TrR
Hot-dip galvanized.	1.26	First R in 225 weeks; all R in 379 weeks					First R in 200 weeks; all R in 434 weeks						0	0	0	0	0	0	0	10Y	20Y	20Y	TrR 99Y	....	0
Cadmium plated...	0.04	First R in 16 weeks; all R in 43 weeks					First R in — weeks; all R in 17 weeks						First R in 16 weeks; all R in 43 weeks						First R in 17 weeks; all R in 96 weeks					First R in 52 weeks; all R in 263 weeks	
Hot-dip galvanized.	....	First R in 199 weeks; all R in 379 weeks					First R in 200 weeks; all R in 330 weeks						0	0	0	0	0	0	0	20Y	0	20Y	TrR 99Y	0	0
Parkerized........	....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 69 weeks						All R in 16 weeks						First R in 17 weeks; all R in 44 weeks					All R in 52 weeks	
Electrogalvanized	....	First R in 43 weeks; all R in 146 weeks					First R in 17 weeks; all R in 174 weeks						50R	50R	60R	80R	80R	80R	....	....	....	....	....		80R

Parkerized.........	....	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 69 weeks						All R in 16 weeks						First R in 17 weeks; all R in 44 weeks					All R in 52 weeks	
Electrogalvanized	....	First R in 43 weeks; all R in 146 weeks					First R in 17 weeks; all R in 174 weeks						50R	50R	60R	80R	80R	80R	....	....	....	....	....	....	80R
Electrogalvanized .	0.21	43R	48R 7Y	57R	60R	73R	78R	80R	82R	82R	83R	83R	0	0	0	0	0	0	0	TrR 1Y	<10R	<10R	<10R	0	0
Electrogalvanized . .	0.16	First R in 95 weeks; all R in 379 weeks					First R in 44 weeks; all R in 305 weeks						3R	4R 2Y	3R	7R	....	<5R	40R	50R	67R	70R	80R	<10R	10R
Hot-dip galvanized .	1.56	TrR	7R 50Y	<10R	20R Y	50R	100Y	....	<10R 95Y	10R 90Y	40R	60R	0	0	0	0	0	0	0	0	0	0	slY	0	0
Cadmium plated . . .	0.12	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 43 weeks; all R in 356 weeks						First R in 17 weeks; all R in 121 weeks					First R in 52 weeks; all R in 305 weeks	
Cadmium plated . . .	0.19	First R in 16 weeks; all R in 95 weeks					First R in 17 weeks; all R in 69 weeks						60R	63R	63R	73R	73R	73R	First R in 17 weeks; all R in 408 weeks					<10R	10R
Electric sherardized.	0.28	First R in 95 weeks; all R in 146 weeks					First R in 96 weeks; all R in 252 weeks						17R 83R	35R 65Y	33R 62Y	63R	73R	90R	First R in 121 weeks; all R in 252 weeks					First R in 162 weeks; all R in 305 weeks	
Gas sherardized....	0.19	First R in 43 weeks; all R in 173 weeks					First R in 17 weeks; all R in 357 weeks						First R in 16 weeks; all R in 43 weeks						First R in 147 weeks; all R in 330 weeks					First R in 52 weeks; all R in 102 week	
Electric sherardized.	0.28	First R in 251 weeks; all R in 459 weeks					60Y	67R 33Y	60R	40R 60Y	70R	90R	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	50Y	100Y
Parkerized.........	....	First R in 16 weeks; all R in 173 weeks					63R*	60R	40R*	60R*	95R	90R	First R in 43 weeks; all R in 407 weeks						First R in 17 weeks; all R in 200 weeks					All R in 52 weeks	
Amaloy............	....	0d	....	0	15R*	10R*	0d	....	0d	0d	0d	0d	80R*	90R	70R*	60R*	70R*	80R*	80R*	77R	50R*	60R*	98R	50R	67R
Hot-dip aluminum. .	1.84	0d	0d	0d	0d	10R*	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	<10R

STEEL HINGES

Cadmium plated....	0.29	First R in 16 weeks; all R in 95 weeks					First R in 17 weeks; all R in 96 weeks						33R	50R	47R	57R	60R	80R	First R in 44 weeks; all R in 278 weeks					10R	30R
Cadmium plated....	0.32	First R in 43 weeks; all R in 95 weeks					First R in 44 weeks; all R in 96 weeks						3R	12R	6R	12R	20R	30R	First R in 69 weeks; all R in 278 weeks					10R	10R
Hot-dip galvanized.	1.54	30R	67R 33Y	50R	60R	90R	50R	75R	80R	50R 50Y	90R	100R	0	0	0	....	....	....	0	0	0	0	TrY	0	0
Electric sherardized.	0.40	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 16 weeks; all R in 95 weeks						First R in 17 weeks; all R in 44 weeks					2R 98Y	17R 83Y
Gas sherardized....	0.68	First R in 120 weeks; all R in 329 weeks					90R	93R	93R	95R	98R	100R	TrR 95Y	2R 98Y	2R 98Y	3R	TrR Y	5R 95Y	40R 50Y	62R 38Y	75R	77R	80R 20Y	<10R 90Y	<10R 95Y
Parkerized.........	....	First R in 95 weeks; all R in 304 weeks					<10R	73R	40R*	50R*	80R	100R	First R in 43 weeks; all R in 199 weeks						First R in 44 weeks; all R in 252 weeks					First R in 52 weeks; all R in 162 weeks	
Electrogalvanized . .	0.19	First R in 16 weeks; all R in 95 weeks					First R in 17 weeks; all R in 96 weeks						60R	....	....	....	....	....	First R in 44 weeks; all R in 408 weeks					First R in 52 weeks; all R in 162 weeks	

BULLDOG CLAMPS

Electrogalvanized . .	3.41	23R	25R 33Y	40R	40R	50R	40R	57R	20R	50R	60R	70R	0	0	0	0	0	0	0	0	0	0	<10R	0	0
Hot-dip galvanized	1.88	TrR 90Y	30R 70Y	....	30R	80R	First R in 252 weeks; all R in 460 weeks						0	0	0	....	....	....	0	0	0	100Y	100Y	0	0
Cadmium plated....	0.22	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 146 weeks; all R in 356 weeks						First R in 17 weeks; all R in 44 weeks					First R in 52 weeks; all R in 162 weeks	
Cadmium plated....	0.17	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 120 weeks						All R in 16 weeks						First R in 96 weeks; all R in 121 weeks					All R in 52 weeks	
Gas sherardized....	0.46	First R in 95 weeks; all R in 277 weeks					First R in 147 weeks; all R in 357 weeks						50Y	100Y	100Y	100Y	100Y	100Y	First R in 147 weeks; all R in 330 weeks					63R 37Y	67R 33Y
Electric sherardized.	1.25	20R	40R 60Y	50R 50Y	70R	80R	25R	....	50R	60R*	75R	100R	50Y	50Y	50Y	100Y	100Y	100Y	100Y	100Y	....	100Y	100Y	50Y	100Y
Electric sherardized.	0.58	First R in 146 weeks; all R in 356 weeks					80R	97R	70R	....	90R	100R	0	0	0d	100Y	100Y	100Y	First R in 226 weeks; all R in 408 weeks					<10R 50Y	100Y
Hot-dip aluminum. .	1.35	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0d	0	....	0	0	TrR	0	0	0	0	0	0	18Y	<10R
Parkerized.........	....	First R in 146 weeks; all R in 356 weeks					TrR	6R	0d	<2Rd	2R	<10R	First R in 43 weeks; all R in 407 weeks						First R in 17 weeks; all R in 174 weeks					All R in 52 weeks	

TABLE VI.—REPORT ON INSPECTIONS OF METALLIC COATINGS ON HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC. (*Continued*).

Racks at Five Locations. Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz., per sq. ft., of surface	Exposure at Brunot Island, Pa.					Exposure at Altoona, Pa.						Exposure at State College, Pa.						Exposure at Sandy Hook, N. J.					Exposure at Key West, Fla.	
		329 weeks	356 weeks	379 weeks	407 weeks	459 weeks	330 weeks	357 weeks	382 weeks	408 weeks	434 weeks	460 weeks	329 weeks	356 weeks	381 weeks	407 weeks	433 weeks	459 weeks	330 weeks	357 weeks	408 weeks	434 weeks	460 weeks	305 weeks	404 weeks
$\frac{1}{4}$ by 3-in. Plain Steel Flats																									
Electrogalvanized	0.76	First R in 120 weeks; all R in 329 weeks					First R in 69 weeks; all R in 226 weeks						0	0	0	0	0	0	16R	19R	40R	43R	60R	0	TrR
Electrogalvanized	0.45	First R in 225 weeks; all R in 379 weeks					First R in 147 weeks; all R in 434 weeks						0	0	0	0	0	0	6R	10R	40R	37R	60R	<10R	<10R
Hot-dip galvanized	2.49	0	1Y	2R	....	....	<5Y	0	<10Y	TrR	TrR	0d	0	0	0	0	0	0	0 Initial Defects	1R Damaged Spots	5R at Defect	5R at Defect	5R Defects	0	0
Hot-dip aluminum	0.90	0d	0d	0d	0d	0d	0d	0	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated	0.23	First R in 43 weeks; all R in 95 weeks					First R in 17 weeks; all R in 69 weeks						38R	63R	62R	83R	87R	95R	First R in 96 weeks; all R in 305 weeks					<10R	<10R
Electric sherardized	....	First R in 146 weeks; all R in 146 weeks					First R in 17 weeks; all R in 147 weeks						100Y	100Y	100Y	2Re Y	TrR 100Y	2R 98Y	First R in 96 weeks; all R in 408 weeks					100Y	100Y
Gas sherardized	0.12	First R in 16 weeks; all R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 43 weeks; all R in 121 weeks						First R in 96 weeks; all R in 305 weeks					First R in 52 weeks; all R in 162 weeks	
Lead plated	....	50R*	32R	30R*	30R*	30R*	0d	....	0d	0d	0d	<5Rd	50R*	70R	60R*	50R*	70R*	75R*	30R*	30R	25R*	25R*	75R*	20R 27Y	37R
$\frac{1}{4}$ by 3-in. Copper Bearing Steel Flats																									
Electrogalvanized	0.84	First R in 120 weeks; all R in 379 weeks					First R in 96 weeks; all R in 305 weeks						0	0	0	0	0	0	27R	30R	....	58R	60R	0	0
Electrogalvanized	0.66	60R	76R	72R	85R	90R	First R in 147 weeks; all R in 382 weeks						0	0	0	0	0	0	7R	10R	23R 2Re	29R	40R	0	0
Hot-dip galvanized	2.67	0	1Y	100R	0	TrY	TrR	1R 10Y	10Y	TrR	TrR	10R	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum	0.66	0d	0	0	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated	0.27	First R in 43 weeks; all R in 95 weeks					First R in 17 weeks; all R in 69 weeks						47R	65R	65R	72R	89R	95R	First R in 44 weeks; all R in 252 weeks					<10R	11R
Electric sherardized	....	First R in 95 weeks; all R in 146 weeks					First R in 121 weeks; all R in 147 weeks						100Y	2R 98Y	TrR 100Y	TrR 100Y	TrR 100Y	<10R 90Y	40R	75R 25Y	83R 13Y	85R	100R	100Y	100Y
Gas sherardized	0.18	All R in 43 weeks					First R in 17 weeks; all R in 44 weeks						First R in 68 weeks; all R in 146 weeks						First R in 44 weeks; all R in 96 weeks					First R in 52 weeks; all R in 162 weeks	
Lead plated	....	50R*	33R	20R*	30R*	30R*	0d	0d	0d	0d	0d	<5Rd	40R*	57R	27R 17R*	30R*	50R*	70R*	20R*	35R	20R*	25R*	30R*	23R	37R
No. 209 Window Frame Sections																									
Electrogalvanized	0.67	First R in 95 weeks; all R in 277 weeks				Rack down	First R in 44 weeks; all R in 382 weeks						6Ra	7Ra	6Ra	7Ra	7Ra	7Ra	<10R	18R	Rack down			<10R	10Ra
Electrogalvanized	0.24		98R	98R	....		First R in 96 weeks; all R in 382 weeks						0	0	0	1R TrY	2Ra	2R	55R	58R				0	<10R
Hot-dip galvanized	3.10		TrY	TrR 2Y	3R		TrY	1R 20Y	TrR	<1R	5R	<5R	0	0	0	0	0	0	0	0				0	0
Hot-dip aluminum	0.61		0d	0d	....		0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0				0	0
Cadmium plated	0.24	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 96 weeks						55R	52R	55R	57R	75R	77R	93R	98R				52R	65R
Electric sherardized	0.52	First R in 146 weeks; all R in 199 weeks					First R in 147 weeks; all R in 252 weeks						100Y	100Y	100Y	TrR Y	TrR Y	<5R 95Y	68R 32Y	85R 15Y				5R 95Y	100Y
Amaloy	....	40R*	42R	55R*			0d	....	0d	0d	0d	0d	70R*	73R	70R*	60R	60R*	80R*	47R*	60R				<10R	40R

No. 792 Window Frame Sections

Electrogalvanized ..	0.54	First R in 43 weeks; all R in 277 weeks					First R in 17 weeks; all R in 357 weeks							16Ra	27Ra	30Ra	25Ra	30Ra	40Ra	50Ra	72R	87R	90R	95R	<10R	<10Ra
Electrogalvanized ..	0.35	First R in 16 weeks; all R in 251 weeks					First R in 17 weeks; all R in 174 weeks							23Ra	33Ra	30Ra	30Ra	30Ra	40Ra	93R	96R	98R	95R	98R	53R	77R
Hot-dip galvanized.	2.60	TrR	1R 3Y	....			TrR	1R 20Y	1R	2R	5R	10R		0	0	0	0	0	0	0	0	0	0	0	0	0
Hot-dip aluminum..	1.39	0d	0	....		Rack Down	0d	0d	0d	0d	0d	0d		0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium plated....	0.22	First R in 16 weeks; all R in 120 weeks					First R in 17 weeks; all R in 96 weeks							7Ra	13R	12Ra	15R	23R	23R	95R 5Y	97R	99R	99R	100R	<10R	17R
Cadmium plated....	0.17	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 69 weeks							51R	65R	72R	73R	83R	95R	First R in 17 weeks; all R in 278 weeks					55R	70R
Electric sherardized.	0.57	63R	80R 20Y	....			First R in 120 weeks; all R in 382 weeks							100Y	100Y	100Y	100Y	100Y	100Y	60R 40Y	68R 32Y	77R 20Y	87R	99R	90Y	100Y
Gas sherardized....	0.58	First R in 68 weeks; all R in 277 weeks					First R in 96 weeks; all R in 382 weeks							40R 60Y	40R 60Y	50R 50Y	53R	50R	65R	100Y	2R 98Y	2R 98Y	5R 95Y	10R 90Y	32R 68Y	40R 60Y
Parkerized.........	....	First R in 43 weeks; all R in 95 weeks					First R in 44 weeks; all R in 252 weeks							First R in 43 weeks; all R in 120 weeks						First R in 17 weeks; all R in 69 weeks					All R in 52 weeks	

No. 161 Window Frame Sections

Electrogalvanized ..	0.89	First R in 16 weeks; all R in 304 weeks					First R in 16 weeks; all R in 382 weeks							27R	27R	44R	27R	35R	40Ra	90R	83R	90R	95R	....	<10Ra	<10Ra
Electrogalvanized ..	0.81	First R in 43 weeks; all R in 304 weeks					First R in 43 weeks; all R in 330 weeks							13R	35R	33R	33R	40R	40Ra	43R	50R	70R	70R	....	28Ra	40Ra
Hot-dip galvanized.	2.97	TrR	TrR	TrR	5R		TrR	1R 10Y	<10R	5R	5R			0	0	0	0	0	0	0	....	....	....	....	0	0
Hot-dip aluminum..	0.66	0d	0d	0d	0d	Rack Down	0d	0	0d	0d	0d		Rack Down	0	0	0	0	0	0	0	....	....	....	....	5Y	TrR
Cadmium plated....	0.22	First R in 16 weeks; all R in 68 weeks					First R in 17 weeks; all R in 69 weeks							73R	83R	82R	80R	90R	90R	97R	....	....	....	....	13R	30Ra
Cadmium plated....	0.15	First R in 16 weeks; all R in 68 weeks					100R		Missing					70R	75R	78R	78R	78R	75R	First R in 17 weeks; all R in 252 weeks					83R	85R
Electric sherardized.	0.32	First R in 146 weeks; all R in 379 weeks					95R		Missing					100Y	100Y	100Y	100Y	100Y	100Y	TrR 100Y	1R 99Y	3R 97Y	3R 97Y	10R 90Y	25Y	100Y
Gas sherardized....	0.42	First R in 146 weeks; all R in 379 weeks					85R		Missing					TrR 100Y	TrR 100Y	<10R 90Y	TrRa Y	2Ra 67Y	5R 95Y	43R	58R 42Y	67R 33Y	77R 23Y	85R 15Y	100Y	100Y
Parkerized.........	....	First R in 43 weeks; all R in 95 weeks					100R		Missing					First R in 43 weeks; all R in 95 weeks						First R in 17 weeks; all R in 96 weeks					All R in 52 weeks	

REPORT OF COMMITTEE A-6
ON
MAGNETIC PROPERTIES

Committee A-6 on Magnetic Properties held no meetings during 1937 and accordingly no report was made to the Society last year but the activities were carried on through subcommittee meetings and correspondence. On February 18, 1938, a meeting of Committee A-6 was held at the Society headquarters in Philadelphia, Pa.

There has been added to the committee the office of vice-chairman, and the subcommittees have been reorganized, comprising an Advisory Committee and the following technical committees:

I on Nomenclature and Definitions (W. J. Shackelton, chairman),
II on Specifications (P. H. Dike, chairman),
III on Direct Current Test Methods (B. M. Smith, chairman),
IV on Alternating Current Test Methods (J. P. Barton, chairman), and
V on Magnetic Analysis (A. V. de Forest, chairman).

Subcommittee V was organized to take over the functions of the former Committee A-8 on Magnetic Analysis, which has been discontinued as a separate standing committee because of reduced activity.

It is with deep regret that the committee records the death of J. A. Capp of the General Electric Co., and of L. E. Howard of the Simonds Saw and Steel Co., who were active and valued members of Committee A-6 for many years.

Since the previous report in 1936, in addition to members transferred from Committee A-8, the following have been added to the personnel of the committee: W. C. Carroll of the Republic Steel Corp.; A. A. Hassan of the Crucible Steel Co. of America (succeeding Kenneth Metcalfe); T. S. Fuller of the General Electric Co. (succeeding J. A. Capp); H. A. Pavitt of the Simonds Saw and Steel Co. (succeeding L. E. Howard); J. P. Barton of the Carnegie Illinois Steel Co. (succeeding O. E. Romig), and Henry Wysor of the Bethlehem Steel Co. Mr. Barton also replaces Mr. Romig as chairman of Subcommittee IV.

Mr. K. L. Scott of the Western Electric Co. has been appointed as a representative of the National Electrical Manufacturers Association in place of Mr. P. H. Dike.

The election of officers for the ensuing term of two years has resulted in the re-election of Thomas Spooner as chairman, P. H. Dike as vice-chairman, and R. L. Sanford as secretary. The two members of the Advisory Committee, in addition to the officers, are J. P. Barton and B. M. Smith.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

Many methods of measuring interlamination resistance are in use and to meet the demand for one standard method, the committee recommends that the Tentative Method of Test for Measuring Interlamination Resistance of Steel, appended hereto,[1] be accepted for publication as tentative. This method is applicable to electrical sheet or strip steel and may be applied to material having only the normal oxide on the surface or to enameled material. It covers simply a method of sampling and a test procedure; no resistance limits are prescribed as this is a function of the specifications for the material. It is intended that the method, when adopted as standard, will be added to the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 36).

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[1] See p. 631.

Revisions of Standards:

The committee recommends for immediate adoption the following revision of the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 36),[1] and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that this modification may be referred to letter ballot of the Society:

Section 7 (f).—Delete this paragraph which reads as follows, relettering the subsequent paragraphs accordingly:

> *(f) Simplex High Magnetization Adapter.*—This type of apparatus may be used for the determination of maximum induction, B_m, residual induction B_r, and coercive force, H_c, of high coercive force materials with the following reservations: B_m and B_r results are sufficiently accurate for commercial tests, assuming uniform specimens; H_c may be low by an amount depending on the thickness of specimen and magnitude of H_c. These errors may vary from 0 to 10 or 12 per cent, the error generally being greater as the thickness of the specimen increases.

The committee recommends for publication as a tentative revision of the Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 36),[2] the following new definition of the term weber, and revised definitions for magnetic induction, and intrinsic induction:

Weber.—Under the Definitions of Units, add a definition for "weber," a unit of magnetic flux, to read as follows:

> *Weber.*—The amount of magnetic flux which, when linked at a uniform rate with a single-turn electric circuit during an interval of one second, will induce in this circuit an electromotive force of one volt.

Magnetic Induction.—Change from its present form: namely,

> *Magnetic Induction (Magnetic Flux Density), B.*—The vector magnetic quantity which, at any point in a magnetic field, determines the electromotive force induced in an electric circuit which is linked with the field at a definite time rate. Thus:
>
> $$e = N\frac{dB}{dt}$$
>
> where e is the electromotive force produced in a circuit which is linked N times with a magnetic field of unit cross-sectional area and of uniform induction B.
>
> Note.—In isotropic materials, magnetic induction and magnetizing force have the same (or opposite) direction. In anisotropic materials (such as single crystals and fabricated metals) the direction of the induction is a function of the magnitude of the magnetizing force, the orientation of the crystal axes of the material and its previous condition of magnetization.
>
> Unit: *Gauss.*

to read as follows:

> *Magnetic Induction, B.*—A vector quantity which, at any point in a magnetic field, determines the electromotive force induced in an elementary conductor that is moving through the field at that point. The value of the electromotive force is proportional to the component of the magnetic induction which is perpendicular to the plane in which the conductor moves, as well as to the product of the length of the conductor, its velocity, and the sine of the angle between the direction of the conductor and the direction of motion. In a vacuum, magnetic induction at a point has the same direction as, and is proportional in magnitude to, the magnetizing force at the point. In material media, magnetic induction is a function of the configurations of the electrons and atoms of the material.
>
> The vector equation connecting magnetic induction and electromotive force is:
>
> $$e = V \times L \times B$$
>
> where L is the length of a conductor moving with velocity V perpendicular to a uniform field of magnetic induction B, and e is the electromotive force produced, all quantities being measured in the same system of units.
>
> Note.—In isotropic materials magnetic induction and magnetizing force have the same (or opposite) direction. In anisotropic materials (such as single crystals and fabricated metals) the direction of the induction is a function of the magnitude of the magnetizing

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 504.

[2] *Ibid.*, p. 518.

force, the orientation of the crystal axes of the material and its previous condition of magnetization.

UNIT: *Gauss.*

Intrinsic Induction.—Change from its present form: namely,

Intrinsic Induction in a Ferromagnetic Material (Ferric Induction), B_i.—For a given value of the magnetizing force, the excess of the normal induction in the material over that in vacuum.

$$B_i = B - \mu_v H$$

UNIT: *Gauss.*

to read as follows:

Intrinsic Induction, B_i.—At any point in a magnetic body, the excess of the induction at the point over that produced in a vacuum by a magnetizing force of the value acting at the point. Thus:

$$B_i = B - \mu_v H$$

UNIT: *Gauss.*

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 24 members; 18 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Method of Test for Measuring Interlamination Resistance of Steel (A 34 – 38 T)	18	0	0
II. REVISIONS OF STANDARDS			
Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 36), immediate adoption	18	0	0
Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 36)	18	0	0

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Nomenclature and Definitions (W. J. Shackelton, chairman).—This subcommittee has held two meetings since presenting its report in 1936. In order to agree more closely with the definitions written by the Sectional Committee on Definitions of Electrical Terms, functioning under the procedure of the American Standards Association (A.S.A. Project: C42), certain changes in the Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 36) have been considered; two revised definitions and one new definition are being recommended for publication as tentative, as given in detail earlier in this report.

Certain terms dealing with incremental permeability phenomena are under consideration, but no definite recommendations are ready to be submitted. There is considerable activity in England in this field at present, and it is felt that no action should be taken until the work there has further crystallized.

Subcommittee III on Direct Current Test Methods (B. M. Smith, chairman).—As a result of round-robin tests on permanent magnet materials of high coercive force, it was found that test values on bars of less than $\frac{1}{2}$ in. in thickness were not in as close agreement as desired. It is recommended, pending an investigation by the National Bureau of Standards and other laboratories, that no bars less than $\frac{1}{2}$ in. in thickness be used for commercial test specimens.

At the suggestion of Mr. F. P. Fahy, it was recommended that the simplex high magnetization adapter be withdrawn from the list of approved methods for high magnetization measurements, because the super-H adapter has now replaced it. The Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 36) are being revised immediately to take care of this recommendation.

Subcommittee IV on Alternating Current Test Methods (J. P. Barton, chairman).—Several meetings of this subcommittee have been held since the previous report. For many years, a variety of tests for interlamination resistance of electrical sheet and strip steel has been in use by various laboratories. These methods and procedures do not give similar results on the same material. Tests for interlamination resistance are desirable in order to give a measure of the comparative effectiveness of various insulating coatings and to insure that the resistance between sheets in a laminated core will not permit sufficient induced currents to flow between laminations so as to affect materially the core losses.

A Tentative Method of Test for Measuring Interlamination Resistance of Steel has resulted from discussion and tests, and is being submitted to the Society for publication as tentative, as appended hereto.[1] Chiefly because of the availability of the samples, it was finally decided to make these tests on a stack of half-length Epstein strips, using values based on the whole surface area of the strips. An alternative method proposed by Mr. G. L. Gaalaas of the Empire Sheet and Tin Plate Co. consisted in measuring the resistance of the contact between a small button and the surface of the sheet under test. A pressure of 50 lb. per sq. in. was used and the average value of a number of tests was reported. This method has certain advantages and disadvantages over the new tentative method and for certain applications may be superior.

Due to variations in surface roughness, enamel thickness, gage variations and other factors, a method of measuring the stacking factor (per cent solid) of laminations is desirable. Methods are being considered by Subcommittee IV, but have not progressed far enough to be presented to the Society.

Other active projects before the subcommittee are the use of the "Baby Epstein" (25-cm. samples) for core loss and alternating-current permeability tests at normal and high inductions; also, methods of determining incremental permeability under conditions of direct-current polarization.

This report has been submitted to letter ballot of the committee which consists of 24 members; 18 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

THOMAS SPOONER,
Chairman.

R. L. SANFORD,
Secretary.

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[1] See p. 631.

REPORT OF COMMITTEE A-9
ON
FERRO-ALLOYS

Since the previous report of Committee A-9 on Ferro-Alloys presented to the Society in 1934, the committee has held two meetings: one in Atlantic City, N. J., on June 29, 1936, and the other in New York City on June 30, 1937. A third meeting will be held prior to the presentation of this report to the Society, at which time the report will be reviewed and other matters considered.

A comprehensive study and review of all of the nine specifications for ferro-alloys under the jurisdiction of the committee have been made by Subcommittee I on Specifications under the chairmanship of Mr. E. A. Lucas. This work has resulted in the preparation of revisions in all of the specifications as mentioned later in this report. Consideration is also being given by Subcommittee I to the preparation of specifications for ferroboron, ferrotitanium, and ferrocolumbium.

The present membership of the committee now totals 28, of whom 8 are classified as producers, 14 as consumers, and 6 as general interest members.

In order to bring the nine existing specifications for ferro-alloys into closer agreement with commercial practice and requirements, the committee has completed revisions in the following standards. The changes have been incorporated in separate tentative specifications appended hereto,[1] which are intended to supersede when adopted the following specifications:

Standard Specifications for:
Spiegeleisen (A 98 – 27)
Ferromanganese (A 99 – 27)
Ferrosilicon (A 100 – 27)
Ferrochromium (A 101 – 27)
Ferrovanadium (A 102 – 27)
Molybdenum Salts and Compounds (A 146 – 34)
Ferromolybdenum (A 132 – 34)
Low-Carbon Ferromolybdenum (A 145-34)
Ferrotungsten (A 144 – 34)

The revised specifications for spiegeleisen (A 98) includes an additional Grade C of which considerable quantities are now being used. The present standard specifications for ferromanganese (A 99) covers only one grade. The revised specifications are being enlarged to include three grades, A, B, and C, of medium-carbon ferromanganese, and two grades, A and B, of low-carbon ferromanganese. The revised specifications will more fully cover this type of ferroalloy.

The three grades, A, B, and C, of ferrosilicon covered by the present Standard A 100 are being revised to include more detailed requirements as to chemical composition and the specifications are being further extended to include three additional grades, D, E, and F. It is believed that the revised specifications will include all grades now available and used commercially.

The principal change in the specifications for molybdenum salts and compounds provides for an increase in the maximum copper content of 0.20 per cent now specified in Standard A 146 to an upper limit of 1.0 per cent. The available product now produced and sold is in line with the new maximum of 1 per cent copper prescribed in the revised specifications.

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[1] See pp. 615 to 629.

The committee can see no necessity for separate specifications for ferromolybdenum and low-carbon molybdenum and the revised specifications appended hereto,[1] which covers two grades, A and B, represents a proposed revision and consolidation of the two existing Standards A 132 and A 145. The molybdenum content has been changed to conform with actual practice since large quantities of ferromolybdenum having a molybdenum content higher than 65 per cent are regularly sold. A very small percentage of ferromolybdenum contains less than 0.25 per cent copper, the general range being about 0.60 to 0.90 per cent. The revised specifications accordingly place an upper limit of 1.0 per cent on the copper content which is the same as that prescribed in the revised specifications for molybdenum salts and compounds.

In order to meet the requirements under which about 95 per cent of domestic ferrotungsten is sold, the revision in Standard A 144 provides for changes in the chemical composition requirements, the principal revision of which is a reduction of the carbon content to 0.60 per cent, maximum, and of manganese to 0.75 per cent, maximum. These changes are desirable since three are very few places today where ferrotungsten containing 0.75 per cent carbon and 1.00 per cent manganese, at present specified, can be used.

After approval by letter ballot vote of Committee A-9 the above recommendations will be submitted to the Society through Committee E-10 on Standards subsequent to the presentation of this report at the annual meeting.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, Charles McKnight
Vice-Chairman, J. H. Crichett
Secretary, C. M. Loeb, Jr.

This report has been submitted to letter ballot of the committee, which consists of 28 members; 20 members returned their ballots, of whom 17 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

CHARLES MCKNIGHT,
Chairman.

J. J. CROWE,
Secretary.

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[1] See p. 625.

EDITORIAL NOTE

Subsequent to the annual meeting Committee A-9 on Ferro-Alloys presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Revisions of Standard Specifications for:

Spiegeleisen (A 98 – 27),
Ferromanganese (A 99 – 27)
Ferrosilicon (A 100 – 27),
Ferrochromium (A 101 – 27),
Ferrovanadium (A 102 – 27),
Molybdenum Salts and Compounds (A 146 – 34),
Ferromolybdenum (A 132 – 34) and Low-Carbon Ferromolybdenum (A 145 – 34), and
Ferrotungsten (A 144 – 34).

The revisions, in the form of new tentative specifications which are intended to replace when adopted the present standard specifications, were accepted by Committee E-10 and appear on pp. 615 to 629.

REPORT OF COMMITTEE A-10

ON

IRON-CHROMIUM, IRON-CHROMIUM-NICKEL AND RELATED ALLOYS

Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys held two meetings during the year: in Rochester, N. Y., on March 11, 1938, during the spring meetings of A.S.T.M. committees, and an informal meeting during the annual meeting of the American Society for Metals on October 19, 1937, in Atlantic City, N. J.

Several changes in committee personnel have occurred resulting in a present membership of 73, of whom 32 are classified as producers, 31 as consumers, and 10 as general interest members. Three members of the committee died during the year: namely, Messrs. R. A. Bull, J. A. Capp, and C. W. Hippensteel. The loss of these members is strongly felt by the entire committee.

Mr. W. J. Jeffries has accepted the vice-chairmanship of Committee A-10, succeeding Mr. C. E. MacQuigg, resigned. He was also re-elected chairman of Subcommittee X. Mr. E. F. Cone has succeeded Mr. MacQuigg as chairman of Subcommittee I on Classification of Data with Mr. R. E. Franks assisting as secretary of this subcommittee. Mr. Franks has also been appointed chairman of Subcommittee VI on Metallography. Messrs. Cone and Franks have been added to the membership of the Advisory Committee. Selection of personnel of Subcommittee XI on Specifications for Tubular Products under Mr. Newell Hamilton has been completed.

A special committee of three members composed of Messrs. W. H. Finkeldey, chairman, A. B. Bagsar, and F. N. Speller reviewed and amended the regulations of the committee following which they were submitted to vote. Although they were duly approved, certain minor changes were favored necessitating further amendment before adoption. This matter will be referred to the special committee and will be discussed at the June, 1938, meeting.

A special subcommittee appointed to inspect architectural installations examined the Chrysler and Empire State buildings in New York City. Buildings in Philadelphia and Atlantic City are to be examined before this subcommittee makes its report. A complete report on this inspection is expected within about six months. The behavior of the corrosion-resisting steels under conditions of actual service installations will be correlated with the previous manufacturing history, and the results of these surveys, when completed, should be of considerable interest and assistance to the architectural and engineering professions in connection with future building construction.

Several specifications for cast and flat products prepared by the committee have been carried as tentative for three years, and these will likely be advanced to standard following discussion at the coming June meeting.

Recommendations Affecting Standards

Revision of Tentative Standard:

The committee recommends that the

Tentative Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate) (A 167 – 35 T)[1] be revised as follows and continued as tentative:

Section 4.—Change the table of chemical composition requirements appearing in this section from its present form to read as shown in the accompanying Table I.

TABLE I.—CHEMICAL REQUIREMENTS.

	Type Number	Carbon, per cent	Manganese, max., per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, per cent	Chromium, min., per cent	Nickel, min., per cent
Grade 1	302	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	17.50	8.00
Grade 2	304	0.08 max.	1.50	0.035	0.030	0.75 max.	17.50	8.00
Grade 3	305	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	18.00	9.00
Grade 4	306	0.08 max.	1.50	0.035	0.030	0.75 max.	18.00	9.00
Grade 5[a]	321	0.10 max.	1.50	0.035	0.030	0.75 max.	17.00	8.00
Grade 6[b]	316	0.08 max.	2.00	0.035	0.030	0.75 max.	16.00	10.00
Grade 7	309	0.20 max.	1.50	0.035	0.030	3.50 max.	12.00	12.00
Grade 8	310	0.25 max.	1.50	0.035	0.030	2.00 max.	22.00	19.00
Grade 9[c]	347	0.10 max.	1.50	0.035	0.030	0.75 max.	17.00	8.00
Grade 10	302—B	0.08 to 0.20[d]	1.50	0.035	0.030	2.00 min.	17.50	8.00
Grade 11	301—X	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	16.00	7.00

[a] Grade 5 shall have a minimum titanium content of four times the carbon content.
[b] Grade 6 shall have a molybdenum content of 2.00 to 4.00 per cent.
[c] Grade 9 shall have a minimum columbium content of ten times the carbon content.
[d] The carbon content may be specified 0.12 per cent, maximum, for Grades 1, 3, 10, and 11.

Section 14.—Change this section to read as follows by the omission of the words in brackets:

14. The various types of finish procurable on strip products shall be as follows:

(*a*) *Cold-Rolled Strip:*
No. 1. Annealed and pickled.
No. 2. Annealed, pickled, and rerolled.
[No. 3. Annealed, pickled, mechanically cleaned or buffed without the use of abrasives.]

(*b*) *Hot-Rolled Strip:*
No. 1. Hot rolled, annealed, and pickled.

Explanation of Finish:

No. 1. For parts requiring maximum amount of deep drawing, for oxidation resistance.

No. 2. Slightly harder temper than No. 1 [or No. 3] finish due to extra cold rolling. Very good surface.

[No. 3. For parts requiring medium amount of deep drawing, for rolling and molding operations. This strip has a bright surface and requires very little polishing to finish.]

Adoption of Tentative Standards as Standard:

The committee recommends for adoption as standard the Tentative Specifications for Corrosion-Resisting Chromium Steels (Sheet, Strip and Plate) (A 176 – 35 T),[1] and Tentative Specifications for High-Strength Corrosion-Resisting Chromium-Nickel Steels (Sheet and Strip) (A 177 – 35 T)[1] which have been published as tentative for the past three years without revision.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 73 members; 42 members returned their ballots, the results being shown in Table I.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Classification of Data (E. F. Cone, chairman).—Data are being collected under eight subgroup chairmen and will be classified and correlated into a form suitable for publication to replace the present Tables of Chemical Compositions, Physical and Mechanical Properties and Corrosion-Resistant Properties of Corrosion-Resistant and Heat-Resistant Alloys prepared by the Committee in 1930.[1]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, pp. 667, 657, 677 (1935); also 1937 Book of A.S.T.M. Tentative Standards, pp. 212, 202, 222.

The work is progressing satisfactorily under the eight subgroups, a special form being used for the collection of data which will include chemical, physical, mechanical, and fabricating properties of the alloys. It is hoped that further progress can be reported at the June meeting.

Subcommittee IV on Methods of Corrosion Testing (E. S. Taylerson, chairman).—A special committee has prepared a recommended procedure for the making of field corrosion tests in chemical engineering environments in liquids or gases which procedure is to be given detailed study by members of the committee and others interested. Modifications or improvements developed as a result of the study will be presented to the committee in June.

A small sub-subcommittee of two members has arranged to inspect the stainless wire products exposed in the Wire Test Program of Committee A-5 on Corrosion of Iron and Steel. Samples will be examined for appearance to decide whether the materials are representative of commercial products, and the remaining unexposed stock will be examined. It is expected that the report on stainless wire will be incorporated in the report of Committee A-5 next year, with whom Committee A-10 is cooperating in these exposure tests.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. REVISION OF TENTATIVE STANDARD			
Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate) (A 167 - 35 T).	38	1	3
II. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Corrosion-Resisting Chromium Steels (Sheet, Strip and Plate) (A 176 - 35 T).......	37	0	5
Specifications for High-Strength Corrosion-Resisting Chromium-Nickel Steels (Sheet and Strip) (A 177 - 35 T)........	37	1	4

Subcommittee V on Mechanical Testing (V. N. Krivobok, chairman).—This subcommittee is continuing its program on the study of elastic properties of the 18 per cent chromium, 8 per cent nickel types of steel after various heat treatments.

Subcommittee VI on Metallography (R. E. Franks, chairman).—This subcommittee reports the completion of a microscopic examination of 18 per cent chromium, 8 per cent nickel steel after various heat treatments. Two heats, containing, respectively, 0.065 per cent and 0.098 per cent carbon were examined and photographs prepared at magnifications of 100 and 750 diameters. A duplex structure has been observed in or near the grain boundaries with the result that re-examination of the low-carbon steel sample heated at 750 C. will be made by cooperators. Following an exchange of comments between subcommittee members, a decision will be reached regarding disposition of the data and whether additional work should be carried on. This should be accomplished prior to the June meeting.

Subcommittee VII on Welding (L. C. Bibber, chairman).—This subcommittee is continuing to cooperate with the Welding Research Committee on problems involving the welding of materials falling within the scope of Committee A-10. Compilation of data on welding and other activities of the subcommittee will be the subject of early discussion.

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[1] *Proceedings*, Am. Soc. Testing Mats., Plates V to XV, Vol. 30, Part I (1930); also published separately.

Subcommittee VIII on Specifications for Wrought Products (F. B. Foley, chairman).—The chairman reports no demand for a specification covering bars and forgings. This subcommittee has been handicapped in determining the need for such specifications because of lack of consumers to form a balanced committee. The activities of this subcommittee will be discussed at the June meeting.

Subcommittee IX on Specifications for Flat Products (C. C. Snyder, chairman).—This subcommittee has prepared revisions in the Tentative Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate) (A 167 - 35 T). These modifications have been approved by Committee A-10 and will be submitted to the Society at the June meeting. The two other specifications under its jurisdiction, namely, Tentative Specifications for High-Strength Corrosion-Resisting Chromium-Nickel Steels (Sheet and Strip) (A 177 - 35 T) and Tentative Specifications for Corrosion-Resisting Chromium Steels (Sheet, Strip and Plate) (A 176 - 35 T), will have been tentative three years in June and should be advanced to standard.

Subcommittee X on Specifications for Castings (W. J. Jeffries, chairman).—This subcommittee has held no meetings during the past year. All of its specifications are now in tentative form. Consideration is being given toward recommending all of the specifications for alloy-steel castings for adoption as standard. A meeting of the subcommittee will be held during the annual meeting in June in order to discuss the adoption as standard of the tentative specifications.

Subcommittee XI on Specifications for Tubular Products (Newell Hamilton, chairman).—This subcommittee is preparing, with the cooperation of the Joint A.S.T.M.-AP.I. Subcommittee, proposed specifications for seamless chromium-nickel austenitic alloy-steel still tubes for refinery service. These specifications will be presented to Committee A-10 during, or shortly after, the June meeting.

Consideration is also being given to the formulation of general specifications for seamless chromium and chromium-nickel stainless steel tubes for corrosion-resisting service, and for welded chromium and chromium-nickel stainless steel tubing. Further effort will likely be made toward obtaining oil refinery consumer members on the subcommittee.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, Jerome Strauss
Vice-Chairman, H. L. Maxwell
Secretary, H. D. Newell.

This report has been submitted to letter ballot of the committee which consists of 73 members; 56 members returned their ballots, of whom 54 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

JEROME STRAUSS,
Chairman.

H. D. NEWELL,
Secretary.

REPORT OF THE RESEARCH COMMITTEE
ON
FATIGUE OF METALS

During the past year the Research Committee on Fatigue of Metals held a meeting in Rochester, N. Y., on March 10, 1938, during the spring group meetings of A.S.T.M. Committees.

At that meeting the question of a proposed research investigation on the effect of type of testing machines on fatigue test results was discussed and referred to letter ballot of the committee for approval. This letter ballot resulted as follows: Out of a membership of 19, 14 members returned their ballots, all of whom voted affirmatively. The committee is accordingly proceeding with its plans and is endeavoring to secure funds for this research. The remainder of this report is devoted to an outline of the proposed research program.

Outline of Investigation of Effect of Type of Testing Machines on Fatigue Test Results:

General Object.—To obtain data which may aid in answering the question: "Are the shape of the *S-N* diagram and the endurance limit obtained from a set of fatigue tests a measure of a property of the metal, or are they affected by the type of machine used, and if so, how much?"

Data Available.—Mr. R. L. Templin of the Aluminum Company Research Laboratories has a considerable amount of fatigue test data on the duralumin-type alloy S-17 which will be available for the proposed research.

Metals to be Studied.—The metals to be studied are: (*1*) A heat-treated alloy steel, and (*2*) "as-rolled" low-alloy steel. Material is to be obtained in the form of round bars slightly larger than the largest diameter of specimen to be used; 250 ft. of each metal is to be obtained. This should provide a good reserve of metal for further tests. It is also planned to get a supply of 8 per cent tin-bronze, if possible, so that if work on another metal can be begun the metal will be available.

Tests to be Made.—It is planned to make ordinary fatigue tests under reversed stress by two laboratories on the following types of machines: (*1*) Ono-R. R. Moore (rotating-beam, two loads), (*2*) rotating cantilever (Woehler-McAdam type), and (*3*) reversed axial stress type (Haigh). All tests are to be run at as nearly the same speed as is possible. Special attention is to be paid to the left-hand (high stress) portion of the *S-N* diagram. Two laboratories are to make duplicate tests, six laboratories in all. Laboratories suitably equipped for making tests have been listed.

Machining Specimens.—In general specimens are to be furnished machined. A suitable minimum number of machined specimens will be furnished, and additional material is sufficient for at least as many more specimens. Thus, machining costs will be held to a minimum. The extra material can be machined for check tests, or for further tests (say, of notched bars). If any laboratory wishes the specimens can be furnished slightly oversize at the parts to fit machine chucks so that the final fitting to chucks can be made at the laboratory where the testing is to be done. In general, for the sake of uniformity, it seems best that the critical sections of the specimens be machined and polished at one place. Probably the machining of specimens will be the principal item of cost.

Preliminary Examination of Material Furnished.—All the bars furnished should be tested along their length for Brinell or Rockwell hardness, and a number of metallographic examinations of crystalline structure should be made for each metal. Any considerable deviation from uniformity as shown by Brinell hardness or by micrographs should lead to securing another bar of metal.

Auxiliary Tests.—The ordinary static properties of the metals should be determined, and possibly notched-bar impact tests run.

Additional Lines of Work.—If found feasible this very modest program can be readily expanded. The rather large reserve of material, which it is proposed to obtain, is planned with such expansion in view. It has already been proposed to try to obtain bars of a copper-tin alloy for expansion of this program, if feasible. Further tests might well include fatigue tests of notched bars, fatigue tests at different speeds, and fatigue tests with other types of machines. Already one laboratory has offered to run tests on the de Forest Raflex machine.

It is to be emphasized that this is a problem of the technique of testing and its effect on results, and not primarily a study of the fatigue properties of any particular metals. Such a problem clearly comes within the range of the special interests of the A.S.T.M.; it seems to the committee to be distinctly an A.S.T.M. problem.

The committee re-elected the present chairman for the ensuing term of two years.

This report has been submitted to letter ballot of the committee which consists of 19 members; 16 members returned their ballots, all of whom voted affirmatively.

Respectfully submitted on behalf of the committee,

H. F. Moore,
Chairman.

REPORT OF JOINT RESEARCH COMMITTEE
ON
EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS
PROGRESS REPORT TO THE SPONSOR SOCIETIES

Meetings:

During the past year meetings were held on November 12, 1937, in Columbus, Ohio; and on March 8, 1938, in Rochester, N. Y. A third meeting of the committee will be held on June 27, 1938, in Atlantic City, N. J., prior to the presentation of this report at the annual meeting of the A.S.T.M.

Finances:

There appears in Table I a summary of the administration of funds during the past year (as of April 15, 1938).

If the present plans on each of the different projects are followed through to completion, under the authorizations made, additional expenditures of about $2200 will be required. Subtraction of this amount from the current balance of about $6000 leaves a reserve of about $3800. Unquestionably, this will be required, possibly with additional funds yet to be secured, in bringing the various projects to a satisfactory conclusion.

Organization and Membership:

The committee records with deep regret the death on July 29, 1937, of R. A. Bull, one of the most active members and chairman of the Finance Committee.

C. E. MacQuigg, formerly of Union Carbide and Carbon Research Laboratories, New York City, who during the year became Dean of the Engineering School, Ohio State University, Columbus, Ohio, retains his membership on the Joint Committee and his chairmanship of Project Committee No. 10.

Subsequent to the presentation of this report, H. J. French, for nine years chairman of the Joint Committee, will be succeeded by N. L. Mochel, who has been vice-chairman for the past two years and secretary of the committee for the seven years between 1929 and 1936. H. J. Kerr will become vice-chairman, while J. W. Bolton will continue as secretary. R. H. Aborn and the present chairman will serve as the two members-at-large of the Executive Committee for a period of two years.

High-Temperature Test Methods:

Changes were made last year in the details of the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (E 21-37 T). The Joint Committee has no further changes to propose at this time, but recommends that the method be continued as tentative for at least another year.

Project Committee No. 14 reviewed the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22-35 T) and recommends that it be extensively revised as appended hereto[1] and continued as tentative.

This recommendation has been submitted to letter ballot of the Joint Committee which consists of 22 members, all the members returned their ballots, of whom 19 voted affirmatively, 0 nega-

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[1] See p. 1301.

TABLE I.—SUMMARY OF RECEIPTS AND EXPENDITURES OF COMMITTEE FUNDS.

Balance shown in 1937 annual report			$14 447.10
	Deduct, to reconcile error in addition in 1936–37 report of expenditures		.22
	Balance at beginning of fiscal year (June, 1937)		$14 446.88
	CASH RECEIPTS		
June, 1937	Utilities Coordinated Research	$750.00[a]	
September, 1937	Interest on fund (1936–1937)	151.79	
January, 1938	Utilities Coordinated Research	750.00[a]	$1 651.79
	EXPENDITURES		
1937 May	Ogilvie Press (Letterheads)	$9.44	
	University of Michigan (Project No. 15)	600.00	
	University of Michigan (Project No. 17)	500.00	$1 109.44
June	Battelle Memorial Institute (Project No. 12)	$250.00	250.00
July	Massachusetts Institute of Technology (Project No. 10)	$2 000.00	
	Battelle Memorial Institute (Project No. 18)	500.00	2 500.00
August	Mack Printing Co. (150 copies Clark-Cross-Lowther Articles)	$23.50	23.50
September	Massachusetts Institute of Technology (Project No. 10)	$1 000.00	
	Battelle Memorial Institute (Project No. 12)	250.00	1 250.00
October	Battelle Memorial Institute (Project No. 18)	$500.00	500.00
December	University of Michigan (Project No. 17)	$500.00	
	Massachusetts Institute of Technology (Project No. 10)	1 000.00	1 500.00
1938 January	Battelle Memorial Institute (Project No. 18)	$1 000.00	1 000.00
February	Mack Printing Co. (Proofs, Robinson Paper)	2.10	2.10
April	Battelle Memorial Institute (Project No. 18)	$894.31	
	Massachusetts Institute of Technology (Project No. 10)	1 000.00	1 894.31
			$10 029.35
Balance on hand, June, 1937			$14 446.88
	Cash receipts		1 651.79
			$16 098.67
Expenditures			10 029.35
	Balance on hand, April 15, 1938		$6 069.32

Total expenditures to April 15, 1938, made on the several research projects currently under way are summarized below:

	Maximum Expenditure Authorized	Payments Made
Project No. 10, Tests of Tubular Members	$6 000.00	$6 000.00
Project No. 11, Assembly Creep Data	2 000.00	1 500.00
Project No. 12, 20,000-hr. Creep Tests	3 250.00	2 750.00
Project No. 13, Low-Temperature Studies	500.00	......
Project No. 14, Revision of Tentative Method E 22 – 35 T	......	......
Project No. 15, Torsion Creep	1 200.00	600.00
Project No. 16, Relaxation Tests	800.00	......
Project No. 17, Life-Test Methods	1 000.00	1 000.00
Project No. 18, Manufacturing Variables *versus* Creep	3 700.00	3 394.31
Project No. 19, Procurement of Materials	......	......
	$18 450.00	$15 244.31

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[a] Represent additional payments under pledges previously made as outlined in the 1937 report, *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 165 (1937).

tively, and 3 members marked their ballots "not voting."

Research Projects:

There follows a summary of progress made in the various research projects during the fiscal year ending June, 1938.

Project No. 10 on Testing of Tubular Members at Elevated Temperatures at the Massachusetts Institute of Technology (C. E. MacQuigg, chairman).—A study of the flow of tubular test specimens subjected to internal pressure at elevated temperatures has been under way at the Massachusetts Institute of Technology, Cambridge, Mass. While the work has not yet progressed far enough to permit direct comparisons of creep under biaxial stresses (obtained in the internal pressure tests) with flow in the same metals at corresponding temperatures, under direct tensile stress, the preliminary results obtained from the newly constructed equipment are summarized briefly in a report by F. H. Norton which appears in Appendix I.

The work on this project, including correlation of tensile-creep tests and the internal-pressure tests, should be completed during the coming year and it is expected a further report will be made at that time.

Project No. 11 on Assembly and Interpretation of Available Creep Test Data at the University of Michigan (P. E. McKinney, chairman).—A report was prepared by this project committee, comprising a foreword, approximately 270 charts, 73 tables, and 430 sheets of primary data. This was presented to the Joint Committee at its March meeting and approved for publication. The size and scope of the project committee's report, and its nature, do not permit an abstract to be included in this review, but arrangements have been made, through the sponsor societies, for publication at the earliest practicable date, in book form. It is planned to have the book on sale beginning in June, 1938, so that the information may be placed in the hands of those interested as soon as possible.

Project No. 12 on Long-Time Creep Tests on Carbon Steel (K20) at Battelle Memorial Institute (H. W. Gillett, chairman).—Progress in this research was reported in detail last year by H. C. Cross and J. G. Lowther.[1]

The exposure of the specimen of 0.35 per cent carbon steel (K20) to stress at temperatures between 840 and 900 F. was continued. This specimen was subjected to 7500 lb. per sq. in. at a temperature of 850 F. for approximately 20,000 hr. (2 yr., 4 months), at which time a total deformation of about 1.55 per cent was shown. During the last 16,000 hr. an approximately constant rate of creep of about 0.000065 per cent per hr. was shown. The committee has always been interested in the effect of small differences in test temperatures on creep rates of steels, and it was felt that this specimen in particular afforded an unusual opportunity for study of this matter. After 20,342 hr. at 850 F., the temperature was reduced to 840 F. for 1000 hr., raised to 860 F. for 1000 hr., reduced to 800 F. for 1000 hr., and raised to 900 F. for 1000 hr. The results obtained are summarized by H. C. Cross and J. G. Lowther and appear in Appendix II to this report.

Project No. 13 on Investigations of the Properties of Metals at Low Temperatures (F. B. Foley, chairman).—In view of the growing interest in low-temperature processes, the industry has itself given much attention to the problems of metals at subatmospheric temperatures. Under these circumstances, time has been spent in determining how best the plans of this project committee could be fitted in with the industrial activity. Discussions were held throughout the year and the project committee was reorganized in March, 1938, under the chairmanship of F. B. Foley, and now plans to initiate an assembly of data comparable to that obtained by Project Committee No. 11 in its field of high-temperature creep-test data. A report is planned for next year.

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[1] "Report on Long-Time Creep Tests of 18 per cent Chromium, 8 per cent Nickel Steel and 0.35 per cent Carbon Steel," *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 178 (1937).

Project No. 14 on Revision of Tentative Method of Creep Tests (E 22 - 35 T) (C. L. Clark, chairman).—The activities of this project committee are referred to under the heading "High-Temperature Test Methods," mentioned earlier in this report. In addition to revising the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 - 35 T), as appended hereto,[1] the project committee has undertaken, during the past few years, a new program of coöperative creep tests on 0.35 per cent carbon steel (K20) at 850 F., to throw further light on the details of the present test method for high-temperature creep tests (E 22 - 35 T). The results of this work are embodied in a report by C. L. Clark which appears in Appendix III.

Table II.—Status of Project No. 16 on Relaxation Tests.
March, 1938.

Material	Source of Material	Temperature, deg. Fahr.	Stress	Status	Test Cooperators
K20 steel	Bethlehem	850	Stress is variable, decreasing as relaxation occurs. Total elastic plus plastic strain of 0.002 is suggested.	complete	Westinghouse E. & M. Co.
K20 steel	Bethlehem	850		complete	General Electric Co.
K20 steel	Bethlehem	850		complete	Crane Co.
Carbon steel		750		complete	General Electric Co.
S.A.E. 4140	Westinghouse	850		complete	Crane Co.
S.A.E. 4140	Westinghouse	850		complete	Westinghouse E. & M. Co.
S.A.E. 4140	Westinghouse	932		complete	Westinghouse E. & M. Co.
Carbon-Molybdenum steel	Crucible and B. & W.	800		not started	Crane Co.
Carbon-Molybdenum steel	Crucible and B. & W.	950		not started	Crane Co.
Carbon-Molybdenum steel	Crucible and B. & W.	1050		not started	Crane Co.
Carbon-Molybdenum steel	Crucible and B. & W.	1050		not started	Babcock & Wilcox Co. and Mass. Inst. Technology
5.0 per cent Chromium, 0.5 per cent Molybdenum	Crucible and B. & W.	1200		not started	General Electric Co.

Project No. 15 on Torsion-Creep Tests for Comparison with Tension-Creep Tests (A. E. White, chairman).—Work under this project was initiated during the second half of the fiscal year ending June, 1938, as a result of unavoidable delays in the procurement of the required tubular test specimens. The progress reports to the Joint Committee indicate that only two or three torsion tests have been started to date. One of these, undertaken at a temperature of 1050 F. and a maximum shear stress of 4000 lb. per sq. in. on carbon-molybdenum steel showed a measurable rate of creep. Tension tests on samples from the same melt of steel have also been under way and a progress report covering comparisons of tension creep and torsion creep may be expected during the coming year.

Project No. 16 on Relaxation Tests (E. L. Robinson, chairman).—Work under this project is being handled without direct expenditures. While the project committee is not yet in a position to submit are port, data have been accumulated steadily, as indicated in Table II. It is expected that a progress report will be available in December.

Project No. 17 on Study of High-Temperature Life-Test Methods (A. E.

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[1] See p. 1301.

White, chairman).—A progress report of this work, by A. E. White and C. L. Clark, comprises Appendix IV to this report.

Project No. 18 on Study of Effects of Manufacturing Variables on the Creep Resistance of Steels (H. W. Gillett, chairman).—This problem received detailed attention during the year and appropriations of $3700 were made for work at the Battelle Memorial Institute. Most of this has already been expended and a detailed report of work prepared by H. C. Cross and J. G. Lowther appears in Appendix V.

In view of the fundamental importance of this study in connection with an understanding of the significance and interpretation of creep tests, a few comments concerning the work of the project committee would appear to be in order. During the year about 12 plain carbon steels with known aluminum additions and one carbon-vanadium steel were tested. Some of these were intentionally coarsened by suitable heat treatments to provide material for comparison of the creep properties of coarse-grained and fine-grained steels. At temperatures of 850 F. and higher, coarse structures in carbon steels showed a decided superiority in creep resistance over fine structures. The carbon-vanadium steel, which showed superior resistance to creep in the usual fine-grained condition, was not improved greatly by coarsening heat treatments.

The results of room-temperature impact tests are interesting in relation to the matter of grain size and its effect on creep properties. It would appear from the preliminary work that a steel which coarsens rapidly on over-heating is not so desirable as one which resists grain coarsening, but which has been coarsened by overheating.

While two 0.45 to 0.50 per cent plain carbon steels showed about the same creep properties at 850 to 950 F., at the same austenitic grain size, the one which coarsened rapidly (at 1650 F.) had an Izod impact value around 4 ft.-lb., whereas, a second which resisted grain coarsening (1800 F. to produce the same grain size) had an Izod impact value at room temperature of 18 ft.-lb.

Purely on a speculative basis, and one requiring further confirmation, it would seem that the best combination of room-temperature notch toughness and high-temperature creep resistance may be secured from partially coarsening steels which would tend to resist coarsening. The reasons for these differences are now being studied and further work is contemplated. Details of the past year's work are given in Appendix V to this report, including results of tests in progress at temperatures below 850 F.

Project No. 19 on Procurement of Materials for Projects Nos. 10, 15, 16, and 17 (H. J. Kerr, chairman).—This committee, coordinating the requirements of the different project committees for test materials, functioned as required during the year and there are no items of special interest to report at this time. However, it seems desirable to include in this report some of the details of the composition and properties of the several steels being distributed to laboratories and used in the sponsored researches of the Joint Committee. This information, prepared by H. J. Kerr, J. B. Romer, and H. D. Newell, is included for reference purposes in Appendix VI to this report.

Miscellaneous Activities:

Through a special committee, headed by R. H. Aborn, U. S. Steel Corporation Research Laboratories, Kearny, N. J., the Joint Committee participated in an exhibit of testing apparatus and related equipment held by the American Society for Testing Materials in New York City, in June, 1937. In addition to an exposition of the committee's work, additional material was assembled to illustrate recent progress in the knowledge of the effects of temperature on metals.

During the fiscal year the Joint Committee and its subcommittees cooperated with various other organizations working in allied fields. For example, some of the information assembled under Project No. 11 was furnished to, and discussed with, the Subcommittee on Ferrous Materials of the A.S.M.E. Boiler Code Committee, and the Joint A.P.I.-A.S.M.E. Code Committee on Unfired Pressure Vessels.

Respectfully submitted on behalf of the Joint Committee,

H. J. FRENCH,
Chairman.
N. L. MOCHEL,
Vice-Chairman.
J. W. BOLTON,
Secretary.

APPENDIX I

PROGRESS REPORT ON CREEP TESTS OF TUBULAR MEMBERS SUBJECTED TO INTERNAL PRESSURE

(PROJECT NO. 10)

PREPARED BY F. H. NORTON

In the past it has been the custom to compute the rate of flow of the metal in pressure vessels on the tension test data applied to the circumferential stresses. However, work of a number of experimenters, particularly those at the National Physical Laboratory in England, has shown that creep is caused mainly by shear stresses, and therefore if we have a lateral stress added to the pure tensile stress the creep may be lower than would be the case in pure tension. In the case of pressure vessels, the circumferential stress has approximately twice the value of the longitudinal stress, which produces a condition of combined stresses which may well cause the flow to be less than that computed from tensile results alone. For this reason the following tests on steel tubes were carried out with internal pressure in order to compare the flow rate under these conditions with tension tests on the same material.

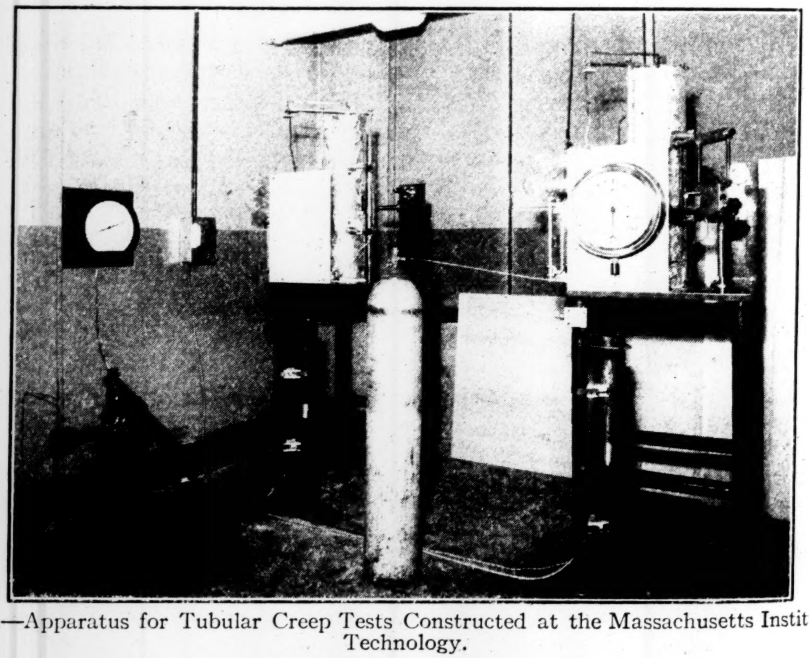

FIG. 1.—Apparatus for Tubular Creep Tests Constructed at the Massachusetts Institute of Technology.

The apparatus used for these tests is

shown in Fig. 1, and consisted of an electrically heated furnace with separate coils so that a uniform temperature could be maintained. The specimens themselves were made of 4-in. tubing with a $\frac{3}{8}$-in. wall, having an over-all length of about 30 in. with welded hemispherical ends. In order to reduce the explosion risk when using gas at high pressure, a filler of solid steel was placed inside the tubes so that a very small annular gas space resulted.

The temperature of the specimen was measured by four chromel-alumel thermocouples tied to the surface at various positions. The temperature was controlled in the same way as with our other creep furnaces by the expansion of the furnace tube itself. While the temperature uniformity over the specimens was not as good as in our tension test furnace, it was held within plus or minus 10 deg. Fahr. in all cases and in the later runs was kept down to ± 2 deg. Fahr.

The pressure in the specimen at the lower pressures was produced with nitrogen from a tank, but at the higher pressures an oil accumulator was necessary to step this pressure up to the desired amount. In three cases there was some leakage from the specimen itself, and one of these was so bad that the run could not be continued more than a few days. However, the tubing connections and valves were found to be perfectly tight, as they were made from designs by Professor Keyes, who has been using them for a number of years at pressures up to 40,000 lb. per sq. in. The gages for measuring the pressures were calibrated before and after the test and were found to be correct within the guaranteed precision.

The elongation both in length and in diameter was measured by the same pair of telescopes on 10-in. centers that is used with our regular tension creep tests. In the case of the length measurement, platinum reference marks were welded on the specimens 10 in. apart, but when measuring the diameter fused quartz struts carried the measurements from the surface of the specimen outside of the furnace.

The steels tested were a carbon-molybdenum steel and a four to six per cent chromium-molybdenum steel having the following compositions:

	CARBON-MOLYBDENUM STEEL	CHROMIUM-MOLYBDENUM STEEL
Carbon, per cent...	0.15	0.09
Manganese, per cent	0.53	0.39
Sulfur, per cent....	0.016	0.016
Phosphorus, per cent	0.016	0.010
Silicon, per cent....	0.21	0.28
Chromium, per cent	....	4.85
Molybdenum, per cent............	0.56	0.53

In Table I are given the preliminary results on the six tests carried out. The tests at 1050 F. have not been completed, so the values here are as yet only approximate. Also the specimens at 800 and 9240 lb. internal pressure and 1200 and 924 lb. internal pressure showed so much leakage during the test that the results

TABLE I.—RESULTS OF TESTS ON TUBULAR MEMBERS UNDER PRESSURE.

	Carbon-Molybdenum Steel, 800 F.		Carbon-Molybdenum Steel, 1050 F.		Chromium-Molybdenum Steel, 1200 F.	
Internal pressure, lb. per sq. in.............	4 000	9 240	1 617	3 230	650	924
Circumferential stress, lb. per sq. in.........	17 350	40 000	7 000	14 000	2 675	4 000
Initial elongation diameter, in. per in........	0.0005	0.0165	0.00025	0.00055	0.00015	......
Initial elongation longitudinally, in. per in...	0.0001	0.0006	0.00007	0.0001	0	......
Rate of creep in diameter, per cent per 100,000 hr...........................	0.7	70 (approx.)	4.5	139	25	15
Rate of creep longitudinally, per cent per 100,000 hr...........................	0.6	......	0.5	0.0	1	0.2

may be open to question. The results all seem to agree among themselves excepting the two runs at 1200 F. where the specimen with the lower pressure gives the higher creep. We have not as yet found any explanation for this. It cannot be due to any large error in measurement of elongation as the final diameter of the specimens in both cases checked closely with the predicted diameter from the extension read by the telescopes. Also we can detect no error in either the temperature or pressure measurements as the gage was calibrated immediately after the test and found correct, and the same was done with the thermocouples.

No definite conclusions can be drawn from this work as yet because the corresponding tensile values are not available. However, it is interesting to note that under certain conditions a pressure vessel may decrease in length during service and under other conditions may increase in length substantially at the same rate as the diameter increases.

DISCUSSION

MR. H. F. MOORE.[1]—I beg leave to present a note on the long-time creep of lead and lead alloys, which may be of interest as indicating the properties of metals which show appreciable creep under ordinary room temperatures. At the University of Illinois specimens of lead sheathing have been under constant internal oil pressure for periods varying from 3000 hr. to 4 yr. In general, the results obtained resemble qualitatively those obtained by Mr. Norton. The longitudinal creep is inappreciable within the sensitivity of our measurements (0.0005 in. over a 20-in. gage length). The circumferential creep has proven very difficult to compare with that of tension specimens, because the full-size sheath specimens have in them many small dents, and have been unwrapped from a coil and straightened. The resulting mechanical imperfections, or some other cause, delay the completion of what may be called the "first stage" of creep—the period before the creep rate becomes nearly constant. However, once a practically constant creep rate is established ("second stage") the creep rate of tension specimens seems to be slightly greater than the circumferential creep rate of full-size sheath specimens. This seems to be in general agreement with Bailey's analysis, although at low stresses we cannot agree with Bailey's finding that creep rate varies as some power of the stress.

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[1] Professor of Engineering Materials, University of Illinois, Urbana, Ill.

APPENDIX II

REPORT ON LONG-TIME CREEP TEST OF 0.35 PER CENT CARBON STEEL (K20)

REPORT TO THE JOINT COMMITTEE COVERING A SPONSORED RESEARCH PROJECT CARRIED OUT AT BATTELLE MEMORIAL INSTITUTE

PREPARED BY HOWARD C. CROSS AND J. G. LOWTHER

This is a final report on the same long-time creep test on which progress reports have previously been made to the sponsor societies.[1,2,3,4]

Material:

Details of the preparation, heat treatment, and properties of this 0.35 per cent carbon steel were given in a previous report to the A.S.M.E.–A.S.T.M. Joint Research Committee on Effect of Temperature on the Properties of Metals.[5]

Creep Test on 0.35 per cent Carbon Steel (K20):

Table I gives a summary of the creep test data. The complete time-deformation curves for specimen 25B5 at 850 F. and 7500 lb. per sq. in. are shown in Fig. 1. It will be noted that a decreasing rate of deformation was shown up to about 4000 hr. From about 4000 to 20,342 hr., an approximately constant rate of deformation was shown varying between 0.00006 to 0.00007 per cent per hr. except for a short period at about 5000 hr. when a lower rate of deformation was observed. Since the rate of deformation in the latter portion of the test was less than the rate observed during the

TABLE I.—CREEP TEST DATA FOR 0.35 PER CENT CARBON STEEL (K20).

Temperature, 850 F.; Load, 7500 lb. per sq. in.; Initial Deformation, 0.05 per cent.

Duration of Test, hr.	Rate of Deformation, per cent per hr.	Total Deformation, per cent
500	0.00012	0.175
1000	0.00012	0.24
1400	0.00010	0.28
2000	0.00009	0.34
3000	0.00009	0.425
4000	0.000075	0.50
5000	0.000025	0.56
6000	0.00007	0.60
7000	0.00006	0.712
8000	0.00006	0.773
9000	0.00006	0.839
10000	0.000065	0.899
11000	0.000065	0.969
12000	0.000065	1.037
13000	0.000065	1.095
14000	0.000065	1.155
15000	0.00007	1.225
16000	0.000065	1.280
17000	0.000065	1.348
18000	0.000065	1.407
19000	0.000065	1.475
20000	0.000065	1.530
20342[a]	0.000065	1.550
21483[b]	0.00004	1.596
22438[c]	0.00008	1.670
0[d]	0	0
1032[e]	0.000013	0.059
2142[f]	0.000355	0.490

[a] Temperature lowered to 840 F.
[b] Temperature raised to 860 F.
[c] Test discontinued; immediate contraction upon release of load, 0.039 per cent.
[d] Test begun on specimen 25B5 at 800 F. Deformation upon application of load, 0.037 per cent.
[e] Temperature raised to 900 F.
[f] Test discontinued; immediate contraction upon release of load, 0.042 per cent.

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[1] H. C. Cross and F. B. Dahle, "Long-Time Creep Tests of 18 Cr 8 Ni Steel and 0.35 per cent Carbon Steel," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 58, No. 2, p. 91 (RP-58–2) (1936).

[2] H. C. Cross and F. B. Dahle, "Report on Long-Time Creep Tests of 18 per cent Chromium, 8 per cent Nickel Steel and 0.35 per cent Carbon Steel," *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 143 (1936).

[3] H. C. Cross and J. G. Lowther. "Long-Time Creep Tests of 18 per cent Chromium, 8 per cent Nickel Steel K19 and 0.35 per cent Carbon Steel K20," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 59, No. 5, p. 441 (RP-59–5) (1937).

[4] H. C. Cross and J. G. Lowther, "Report on Long-Time Creep Tests of 18 per cent Chromium, 8 per cent Nickel Steel and 0.35 per cent Carbon Steel, *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 178 (1937).

[5] "Short-Time Tensile Tests at 850 F. of the 0.35 per cent Carbon Steel Material K20," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 58, No. 2, p. 97 (RP-58–4) (1936).

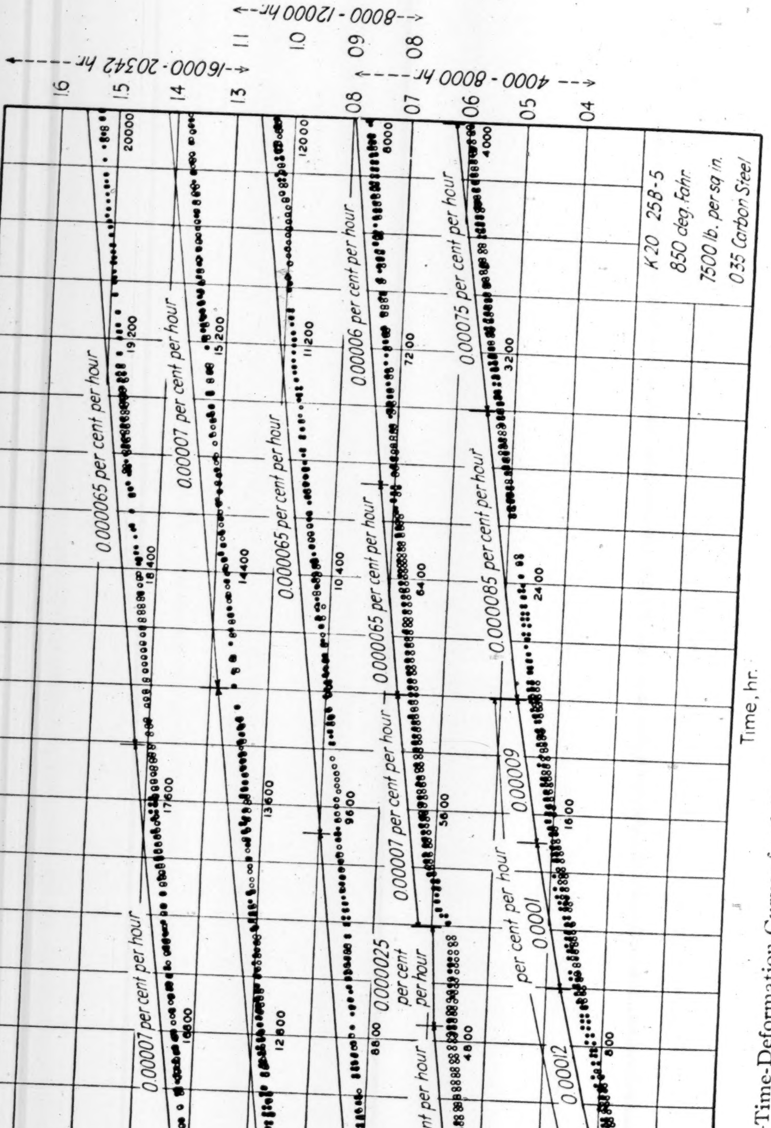


Fig. 1.—Time-Deformation Curves for 0.35 per cent Carbon Steel (K20) at 850 F. and 7500 lb. per sq. in.

first 2000 hr., extrapolation from the early stages of this particular test produces a computed deformation greater than the actual observed deformation. This difference is on the conservative side.

Apparently the load of 7500 lb. per sq. in. at 850 F. for this annealed 0.35 per cent carbon steel (K20) is just on the border line where strain-hardening and annealing balance each other and produce a constant rate of deformation over a long period of time. Previous reports indicated that for this steel at the slightly higher load of 8000 lb. per sq. in. at 850 F., the minimum rate was obtained between about 5000 and 7000 hr. and after that time the rate of deformation began to increase.

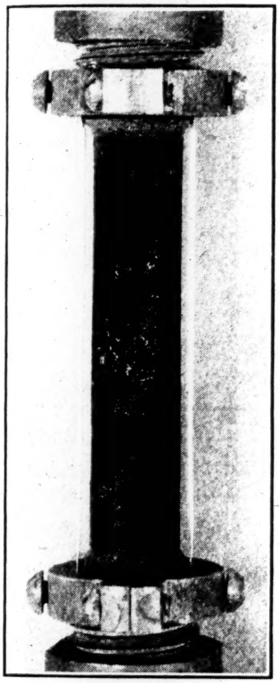


FIG. 2.—Creep Test Specimen 25B5, 0.35 per cent Carbon Steel (K20) After 20,342 hr. at 850 F., and 1000 hr. at 840 and 860 F., Total Deformation, 1.67 per cent.

Temperature-Creep Characteristics of 0.35 per cent Carbon Steel (K20) at a Load of 7500 lb. per sq. in.:

Many other laboratories ran creep tests on this same K20 steel at 850 F. and 7500 lb. per sq. in., but several ran their tests at temperatures slightly lower or higher than 850 F. These data are reported in Appendix III to this annual report of the Joint Research Committee.

In drawing up the A.S.T.M. Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Material (E 22 - 35 T), the Joint Research Committee has always been interested in the effect of small differences in the test temperature on the creep rates. It was felt that this long-time creep test specimen (25B5)

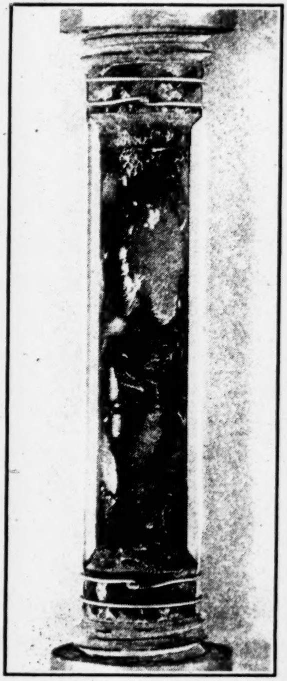


FIG. 3.—Creep Test Specimen 25B5, 0.35 per cent Carbon Steel (K20) After 20,342 hr. at 850 F., and 1000 hr. at 840, 860, 800 and 900 F., Total Deformation, 2.16 per cent.

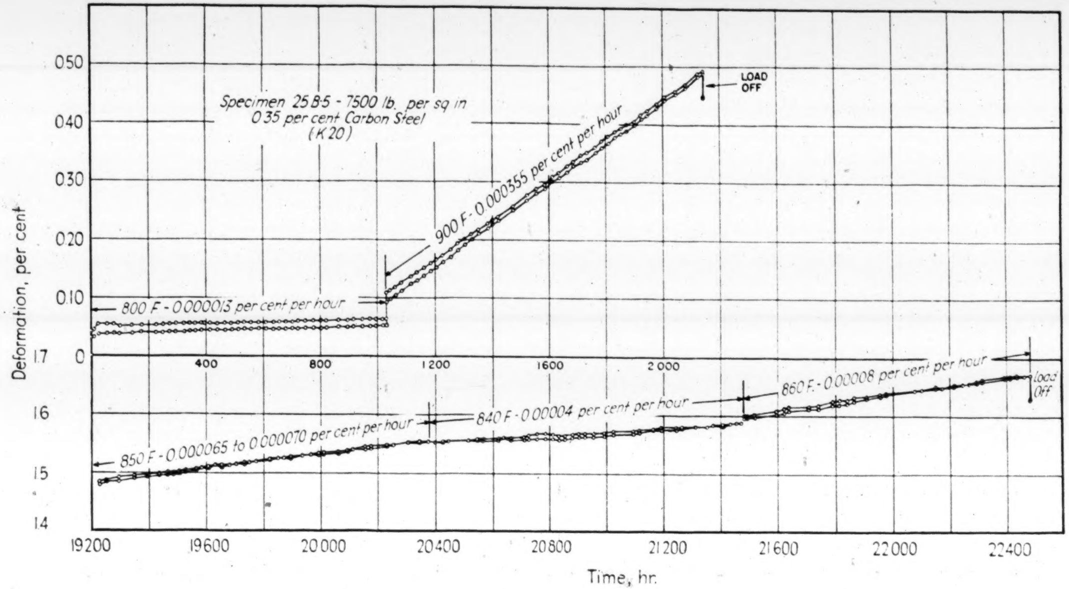


FIG. 4.—Time-Deformation Curves for 0.35 per cent Carbon Steel (K20) at 840, 860, 800 and 900 F.

afforded an unusual opportunity for determination of the effect of small temperature changes on the creep rate of this 0.35 per cent carbon steel (K20). Creep rates observed at temperatures other than but close to 850 F. may be properly ascribed to those temperatures when obtained on a specimen which had obviously long since attained equilibrium conditions.

After 20,342 hr. at 850 F., the temperature was reduced to 840 F. for 1000 hr., and then raised to 860 F. for 1000 hr., after which the specimen was unloaded and cooled to room temperature.

Figure 2 shows the appearance of the test specimen when removed at 22,438 hr. after the 1000-hr. period at 860 F.

TABLE II.—TENSION TEST DATA.

Specimen Number and Identification	Yield point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Reduction of Area, per cent
Bethlehem 6A[a].....	......	69 000	38.0	65.8
Bethlehem 6A[b].....	47 040	68 110	41.6	67.8
Bethlehem 25B[a]......	......	69 000	38.0	64.7
After creep test 25B5[b].	43 310	66 250	36.5	66.9

[a] Standard 0.505-in. diameter—2-in. gage length.

[b] 0.250-in. diameter—1-in. gage length.

The specimen had a reddish-brown oxide scale, which was quite adherent. Near the fillets some areas may be seen where flaking-off had occurred, exposing a second very adherent scale coating.

The heating furnace was calibrated for temperature uniformity at 800 and 900 F., after which the test specimen was replaced in the furnace, heated to 800 F. and loaded for 1000 hr., after which the temperature was raised to 900 F. for 1000 hr. and the test was then discontinued. Figure 3 shows the appearance of the test specimen when removed after completion of the test period at 900 F.

The faster rate of deformation at 900 F. caused more of the original oxide coating to chip off but a very adherent coating either existed beneath or was immediately formed.

Figure 4 shows the time-deformation curves for about the last 1200 hr. at 850 F., and for the 1000-hr. periods at 840, 860, 800, and 900 F. The following table shows the rates of deformation obtained at the various temperatures used:

TEMPERATURE OF CREEP TEST, DEG. FAHR.	RATE OF DEFORMATION, PER CENT PER HR.
800...........	0.000013
840...........	0.00004
850...........	0.000065 to 0.00007
860...........	0.00008
900...........	0.000355

It is indicated that a change in test temperature of 50 deg. Fahr. either above or below 850 F. results in a change in the creep rate of 5 to 1 for this 0.35 per cent carbon steel (K20). Attention is called to the fact that the variations in rate of deformation with temperature observed in this test apply only to this particular K20 steel with its own particular heat treatment and structure. It is not to be taken for granted that other carbon steels or similar steels with different heat treatments would show similar results as regards the effect of temperature on the rate of deformation.

Examination of Specimen 25B5 after Termination of the Creep Test:

Various members of the Joint Research Committee had indicated that room temperature tensile and impact properties of the creep test specimen would be of extreme interest for comparison with these same properties of the steel before creep test. It was also requested that a careful survey of the structure before and after test be made. To comply with all of the requests, the following procedure was used.

Tensile Properties.—For the room temperature tensile properties, at one end of the 2.3-in. gage length of the creep test specimen, a 1-in. gage length cf 0.250 in. diameter was machined.

This smaller diameter was chosen so as not to stress too highly during the tension test the remainder of the 0.505-in. diameter of the reduced section to be used for machining a round 0.450-in. diameter Izod impact test specimen. For comparison, another specimen was machined from K20 steel (as heat treated) in the same manner, with a 1-in. gage length of 0.250 in. diameter at one end of the 2.3-in. gage length. Both specimens were broken in tension at room temperature and the results obtained are shown in Table II. Also listed in Table II are the values supplied by the steel supplier, the Bethlehem Steel Co. for the mill lengths from which the tension test specimen and the creep test specimen were taken.

The tension test data indicate very small differences between bar 6A with 0.250-in. diameter and bars 6A and 25B with standard 0.505-in. diameter. Compared with the average of the three specimens tested as heat treated, specimen 25B5 after creep test shows the yield point lowered about 3700 lb. per sq. in. to 43,310 lb. per sq. in., the tensile strength lowered about 2450 lb. per sq. in. to 66,250 lb. per sq. in., the elongation lowered about 2.5 per cent to 36.5 per cent, and the reduction of area about the same at 66.9 per cent. These are small differences indeed, and it may be said that no significant differences in tensile properties resulted from the time under temperature and load in the creep test.

Impact Resistance.—After cutting a disk 0.2 in. thick from the other half of the 0.505-in. diameter of the reduced section of the creep test specimen 25B5 for purposes of metallographic examination, the remainder was machined into a round (0.450-in. diameter) Izod impact test specimen. The notch was located in the original reduced section of the creep test specimen about 0.25 in. from the fillet. For purposes of comparison a similar specimen was machined from the other half of test bar 6A (as heat treated). Their impact resistances are shown in Table III, along with the results previously obtained on K20 as heat treated and on creep test specimen 10A4 tested for 10,955 hr. at 8000 lb. per sq. in. at 850 F.

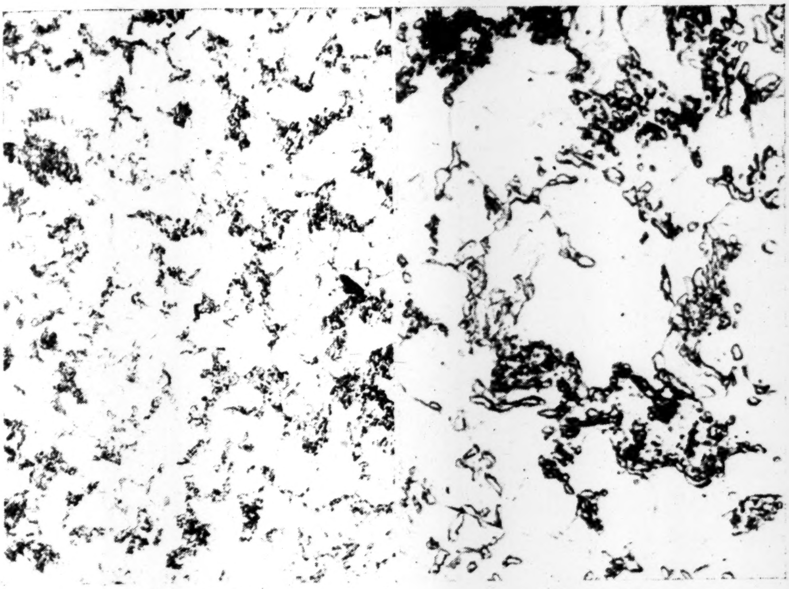
As heat treated, this K20 steel showed Izod impact resistance ranging from 48 to 58 ft-lb. Creep test specimen 10A4 showed 58 ft-lb. and creep test specimen 25B5 showed 56 ft-lb., indicating that the time under load and temperature in the creep tests produced practically no change in impact resistance.

Structure.—Figure 5 at 500 and 1000 magnification shows the structure of this 0.35 per cent carbon steel (K20) as heat treated by slow cooling from 1550 F. The carbides are partially spheroidized and some agglomeration is evident.

TABLE III.—IZOD IMPACT RESISTANCE (ROUND 0.450 IN. DIAMETER).

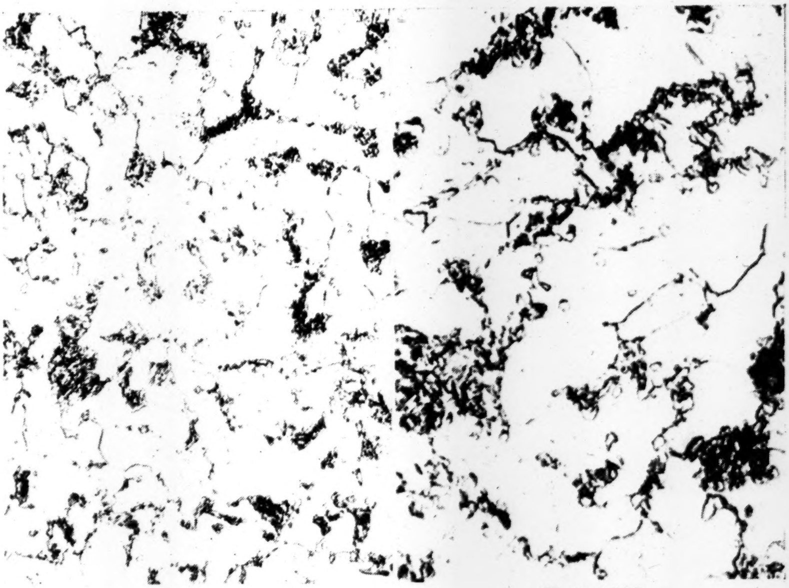
Specimen Number and Identification	Impact Resistance, Ft-lb.
41B, as heat treated....................	48 to 55
6A, from tensile test bar (as heat treated)	58
10A4, after creep test of 10955 hr. at 850 F............................	53 to 55
25B5, after creep test of 20342 hr. at 850 F. and 1000 hr. at 860, 840, 800 and 900 F.	56

Figure 6 also at 500 and 1000 magnification shows the structure at the center of the section of creep test specimen 25B5 after 24,580 hr. at 800 to 900 F., with 20,342 hr. of the total at 850 F. Comparing Figs. 5 and 6, it may be seen that possibly a little more carbide is spheroidized and agglomerated but that very little change in structure has taken place. The annealing treatment used on this steel would be expected to produce and apparently did produce a very stable structure little affected by long times at moderate elevated temperatures such as 800 to 900 F. This stability of structure no doubt accounts for the very small changes in physical properties



(*a*) × 500. (*b*) × 1000.

FIG. 5.—0.35 per cent Carbon Steel (K20), Slow-Cooled from 1550 F.
Etched in 2 per cent Nital.



(*a*) × 500. (*b*) × 1000.

FIG. 6.—Creep Test Specimen 25B5 After Creep Test, 0.35 per cent Carbon Steel (K20), After 20,342 hr. at 850 F., and 1000 hr. at 840, 860, 800 and 900 F.
Etched in 2 per cent Nital.

observed due to time at temperature under load in the creep test. The approximately constant rate of creep between about 4000 and 20,342 hr. was obtained due to the fact that the structure was stable and not changing constantly with time to produce structures of changing creep resistance. Figure 7 shows the structure at the surface of the reduced section of creep test specimen 25B5. The structure at the surface appears similar to that observed at the center as shown in Fig. 6. Apparently the oxide coating prevented any noticeable decarburization, for pearlite and carbide patches were observed unchanged right up to the surface.

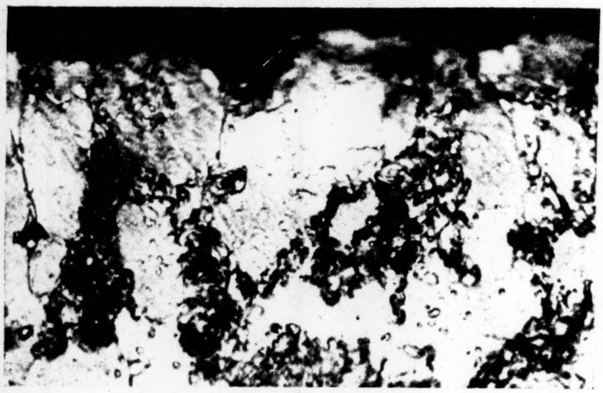


FIG. 7.—Structure at Surface of Creep Test Specimen 25B5, 0.35 per cent Carbon Steel (K20) After 20,342 hr. at 850 F. and 1000 hr. at 840, 860, 800 and 900 F. (× 1000). Etched in 2 per cent Nital.

Conclusions:

The long-time creep test on this annealed 0.35 per cent carbon steel K20 at 850 F. indicates extrapolation from the 2000 hr. period to be conservative as compared with the actual deformation measured over 20,000 hr. An approximately constant rate of deformation was obtained between about 4000 and 20,342 hr.

Experiments on effect of temperature on the creep rate while loaded to 7500 lb. per sq. in. indicate a change of creep rate of 5 to 1 for temperature change 50 deg. Fahr. below or above 850 F.

Tensile and impact tests on the specimen 25B5 after creep test indicate very small and unimportant changes in physical properties to have occurred due to the time at temperature under load.

Examination of the structure indicates little or no change from that shown for the material as heat treated and before creep test. This very stable structure no doubt accounts for the long period of constant creep rate and unchanged physical properties.

DISCUSSION

Mr. Ernest L. Robinson[1] *(by letter).*—The test results at five different temperatures from 800 to 900 F. given in Fig. 4 of Appendix II furnish valuable information on the temperature characteristics of this particular material in this temperature range which are very useful for analysis of the test results at other temperatures than 850 F. as given in Appendix III, the report covering coöperative tests by various laboratories on this material.

The rate of change in creep rate expressed as a percentage per degree Fahrenheit change in temperature may be found very easily by taking the natural logarithm of the ratio of the creep rates at 900 F. and 800 F. At 900 F. the material creeps 27.3 times as fast as at 800 F. The natural logarithm of 27.3 is 3.30 which is (according to the compound interest rule followed by many materials) the percentage change of rate per degree.

Since the rate at 800 F. is very small and the test at that temperature lasted only 1000 hr., it might be preferable to compare the well defined rapid rate at 900 F. with the long standing rate at 850 F. The total creep between 10,000 hr. and 20,000 hr. amounted to 0.63 per cent. This is slightly smaller than the values cited by the authors, but it represents a long-time average. The rate at 900 F. was thus 5.63 times as fast. Since this is for a 50-deg. difference, two times the natural logarithm gives 3.46 as the percentage change of rate per degree Fahrenheit.

The authors have pointed out that these results characterize this particular material and set of conditions. They should not be applied to other materials and temperatures. Furthermore, certain fluctuations from exact performance are to be expected, since the results of the long-time test show rates at certain periods as much as 10 per cent greater than at other times.

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[1] Turbine Engineering Dept., General Electric Co., Schenectady, N. Y.

APPENDIX III

REPORT COVERING CREEP TESTS ON 0.35 PER CENT CARBON STEEL (K20) AT 850 F. UNDER A STRESS OF 7500 LB. PER SQ. IN.

(PROJECT NO. 14)

PREPARED BY C. L. CLARK

Scope:

The purpose of the investigation covered in this report was to ascertain the degree of agreement in creep results which could be obtained by different laboratories through the use of the test procedures prescribed in A.S.T.M. Tentative Methods for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 - 35 T).[1]

In comparative work of this type it is of vital importance to use for test purposes a steel with as high a degree of uniformity as possible. Such material was available in the form of an open-hearth 0.35 per cent carbon steel (designated as K20) which was made by the Bethlehem Steel Co. and had previously been used by Committee III-D in its comparative short-time tensile tests at 850 F. This material was completely described in the report of Committee III-D at the December, 1935, meeting of The American Society of Mechanical Engineers.[2] The chemical analysis, microstructure, tensile properties, and hardness values of the individual 1-in. bars indicated a high degree of uniformity. The actual physical properties of the individual bars used in these tests, together with their composition and heat treatment, are given in Table I.

An open invitation was extended to all laboratories to cooperate and nine requested material for tests. Eight of those nine laboratories have submitted their findings, and the ninth has indicated that results will not be forthcom-

TABLE I.—CHARACTERISTICS OF THE INDIVIDUAL K20 STEEL BARS USED IN THE COOPERATIVE CREEP TESTS.

ROOM TEMPERATURE PHYSICAL PROPERTIES:

Bar	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness
No. 7B.........	70 000	36.5	65.8	131
No. 13A.........	69 500	38.0	65.8	128
No. 14A.........	69 500	38.0	65.8	128
No. 23A.........	69 000	39.0	65.8	128
No. 24A.........	69 000	39.0	65.8	128
No. 25A.........	69 000	38.0	65.8	128
No. 25B.........	69 000	38.0	64.7	131
No. 26A.........	69 000	38.0	65.8	131
No. 26B.........	69 500	37.5	64.7	131
Range.........	69 000 to 70 000	36.5 to 39.0	64.7 to 65.8	128 to 131

CHEMICAL COMPOSITION:

Bar	Carbon, per cent	Manganese, per cent	Silicon, per cent	Sulfur, per cent	Phosphorus, per cent
No. 7.......	0.35	....	....	.....	.....
No. 13.......	0.35	....	....	.....	.....
No. 14.......	0.36	....	....	.....	.....
No. 23.......	0.36	....	....	.....	.....
No. 24.......	0.35	....	....	.....	.....
No. 25.......	0.35	....	....	.....	.....
No. 26.......	0.35	....	....	.....	.....
Average...	0.35	0.55	0.19	0.030	0.016

HEAT TREATMENT:

1. Heated to 1550 F. in 2 hr., held 1 hr. and furnace cooled to 1000 F. from which temperature the bars were air cooled.
2. Reheated to 1280 F. in 4 hr., held 2 hr. and cooled in the furnace to 1000 F., then air cooled.
3. After straightening bars, heated to 950 F. and air cooled.
4. Bars again heated to 950 F. and air cooled.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1291 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1544.

[2] A full description of this material is given in "Short-Time Tensile Tests at 850 F. of the 0.40 per cent Carbon Steel, Material K-20," Report of Subgroup D of Subcommittee 3, *Transactions*, Am. Soc. Mechanical Engrs., February, 1936, pp. 97-101.

ing. The eight cooperating laboratories are as follows:

The Babcock & Wilcox Co. (Massachusetts Institute of Technology)
Battelle Memorial Institute
Bethlehem Steel Co., Inc.
Crane Co.
General Electric Co.
The Midvale Co.
Timken Roller Bearing Co. (University of Michigan)
U. S. Steel Corp., Research Laboratory

TABLE II.—TOTAL DEFORMATION (ELASTIC PLUS PLASTIC) OBTAINED BY COOPERATING LABORATORIES AT DESIGNATED TIME PERIODS.

Steel K20 (0.35 per cent Carbon) at 850 F., 7500 lb. per sq. in. Stress.

Laboratory and Specimen Designation	Total Deformation at Indicated Time Period, per cent								
	0	250 hr.	500 hr.	750 hr.	1000 hr.	1500 hr.	2000 hr.	2500 hr.	3000 hr.
1-25B	0.042	0.134	0.178	0.209	0.244	0.295	0.340	0.379	0.424
2-14A	0.037	0.135	0.180	0.217	0.246	0.294	0.337	0.378	0.417
3-23A (1)	0.043	0.144	0.179	0.217	0.237	0.288	0.333	0.381	0.418
3-23A (2)	0.055	0.153	0.180	0.220	0.235	0.294	0.329	0.377	0.414
4-7B	0.028	0.103	0.157	0.192	0.215	0.268	0.310	0.364	0.406
5-23A	0.033	0.141	0.166	0.208	0.246	0.274	0.308	0.356	.....
6-13A	0.036	0.121	0.154	0.183	0.210	0.256	0.296	0.330	0.365
7-25A	0.035	0.115	0.153	0.177	0.203	0.240	0.277	0.309	.....
Maximum range	0.028 to 0.055	0.103 to 0.153	0.153 to 0.180	0.177 to 0.220	0.203 to 0.246	0.240 to 0.295	0.277 to 0.340	0.309 to 0.381	0.350^a to 0.424
Maximum difference	0.027	0.050	0.027	0.043	0.043	0.055	0.063	0.072	0.074
Average	0.037	0.131	0.168	0.203	0.230	0.276	0.316	0.359	0.407
Range in modulus	26,800,000 to 13,600,000 lb. per sq. in.								
Average modulus	20,270,000 lb. per sq. in.								

[a] Estimated.

On the basis of preliminary work it was agreed that each laboratory would conduct a single test at 850 F. under a stress of 7500 lb. per sq. in. The duration of the test was placed at 1000 to 2000 hr., although, as will be shown later, all tests were extended for longer time periods.

Test Results:

The results were submitted by the cooperators in either tabular or graphical form. The majority of the tests were conducted in conformance with the A.S.T.M. methods mentioned above. A few were conducted at temperatures other than 850 F. and they will therefore be considered separately, especially since only two of these met the requirement with respect to permissible temperature variations over the gage section of the specimen.

Tests in Conformance with the Test Methods and at 850 F.:

The results obtained by seven of the eight cooperating laboratories are shown graphically in Fig. 1. Each laboratory is designated by a number which does not, however, correspond to the alphabetical listing. The number of the steel bar from which the specimen was taken is likewise indicated.

Certain of the laboratories conducted check tests. In order to avoid confusion, however, the results for the duplicate tests are not included in the figure even though both were in conformance with the A.S.T.M. methods. The complete results are considered in the tabular presentation and the degree of agreement thus indicated.

Likewise certain of the laboratories conducted their tests for very extended

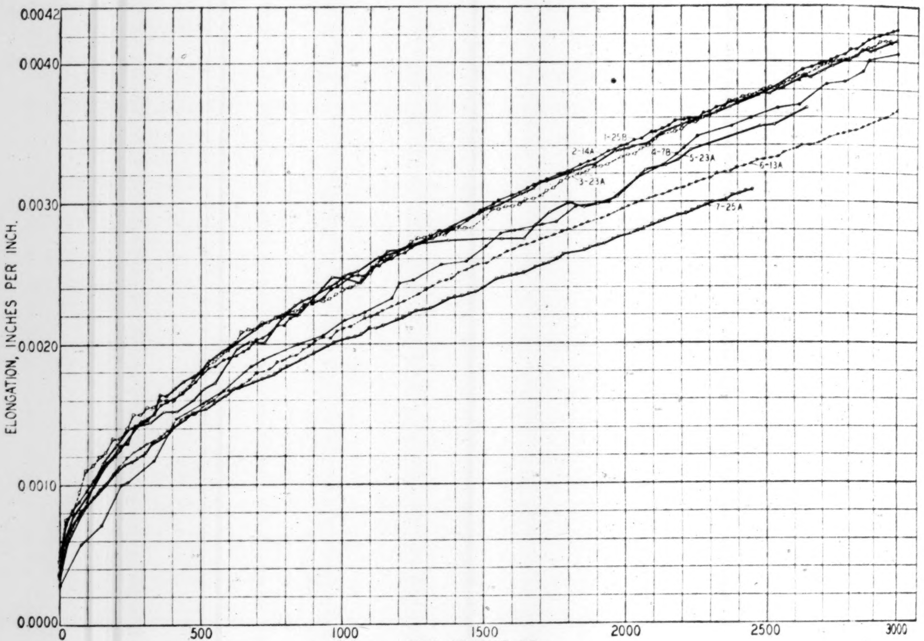

FIG. 1.—Time-Elongation Curves Obtained by Cooperating Laboratories on Steel K20 at 850 F. Under a Stress of 7500 lb. per sq. in.

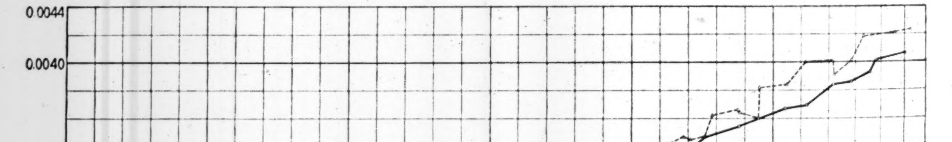

FIG. 2.—Time-Elongation Curves Reported by Laboratory 4 with Original and Improved Extensometer System.

time periods. Since the main purpose of the work is a comparison of the results from various laboratories, a maximum testing time period of 3000 hr. was selected as representative of the testing time period employed by the majority of the laboratories.

TABLE III.—PLASTIC DEFORMATION OBTAINED BY COOPERATING LABORATORIES AT DESIGNATED TIME PERIODS.

Steel K20 (0.35 per cent Carbon) at 850 F., 7500 lb. per sq. in. Stress

Laboratory and Specimen Designation	Deformation at Indicated Time Period, per cent							
	250 hr.	500 hr.	750 hr.	1000 hr.	1500 hr.	2000 hr.	2500 hr.	3000 hr.
1-25B	0.092	0.136	0.167	0.202	0.253	0.298	0.337	0.382
2-14A	0.098	0.143	0.180	0.209	0.257	0.300	0.341	0.380
3-23A (1)	0.101	0.136	0.174	0.194	0.245	0.290	0.338	0.375
3-23A (2)	0.098	0.125	0.165	0.180	0.239	0.274	0.322	0.359
4-7B	0.075	0.129	0.164	0.187	0.240	0.282	0.336	0.378
5-23A	0.108	0.133	0.175	0.213	0.241	0.275	0.323	.....
6-13A	0.085	0.118	0.147	0.174	0.220	0.260	0.294	0.329
7-25A	0.080	0.118	0.142	0.168	0.205	0.242	0.274	0.315[a]
Maximum range	0.080 to 0.108	0.118 to 0.143	0.142 to 0.180	0.168 to 0.213	0.205 to 0.257	0.242 to 0.300	0.274 to 0.341	0.315[a] to 0.382
Maximum difference	0.028	0.025	0.038	0.045	0.052	0.058	0.067	0.067
Average	0.092	0.130	0.164	0.191	0.238	0.278	0.321	0.360

[a] Estimated.

TABLE IV.—CREEP RATES OBTAINED BY COOPERATING LABORATORIES AT DESIGNATED TIME PERIODS.

Steel K20 (0.35 per cent Carbon) at 850 F., 7500 lb. per sq. in. Stress

Laboratory and Specimen Designation	Creep Rate at Indicated Time Period, millionth in. per inch per hr.							
	250 hr.	500 hr.	750 hr.	1000 hr.	1500 hr.	2000 hr.	2500 hr.	3000 hr.
1-25B	2.32	1.60	1.25	1.25	0.97	0.90	0.82	0.82
2-14A	2.44	1.60	1.21	1.14	0.94	0.86	0.78	0.75
3-23A (1)	1.50	1.35	1.20	0.88	0.66	0.66	0.66	0.66
3-23A (2)	1.95	1.55	1.14	0.70	0.65	0.66	0.70	0.65
4-7B	2.87	1.21	0.94	0.94	0.86	0.94	0.82	0.82
5-23A	1.58	1.46	1.20	1.20	0.90	0.90	0.90	....
6-13A	1.58	1.40	1.12	1.03	0.83	0.75	0.68	0.67
7-25A	1.62	1.21	0.99	0.77	0.75	0.73	0.72	....
Maximum range	1.50 to 2.87	1.21 to 1.60	0.94 to 1.25	0.70 to 1.25	0.65 to 0.97	0.66 to 0.94	0.66 to 0.90	0.65 to 0.82
Maximum difference	1.37	0.39	0.31	0.55	0.32	0.28	0.24	0.17
Average	1.98	1.42	1.13	0.99	0.82	0.80	0.76	0.73

From the time-elongation curves of the type given in Fig. 1, the total deformation and the creep rates can be obtained at the desired time periods.

Table II gives the deformation at the indicated time periods. In the table the deformation occurring upon the application of the load is included and the reported values do, therefore, include both the elastic and the plastic deformation.

The deformations obtained upon the application of the 7500 lb. per sq. in. stress range from 0.028 to 0.055 per cent, with an average value of 0.037 per cent. This corresponds to modulus of elasticity values of 26,800,000 to 13,600,000, or an average of 20,270,000 lb. per sq. in. The observed range may be largely due to differences in the time period required for applying the load.

Differences likewise exist in the reported total deformation at each of the time periods considered and these tend to become greater as the testing time is extended. While, on a percentage basis, these differences may appear to be large, the agreement is believed to be good when consideration is given to the sensitivity of the creep resistance and to the magnitude of the values being measured.

Table III differs from Table II only in that it considers plastic, rather than total, deformation. The observed differences are of the same order of magnitude as in the previous table, although the relative position of certain of the laboratories is changed.

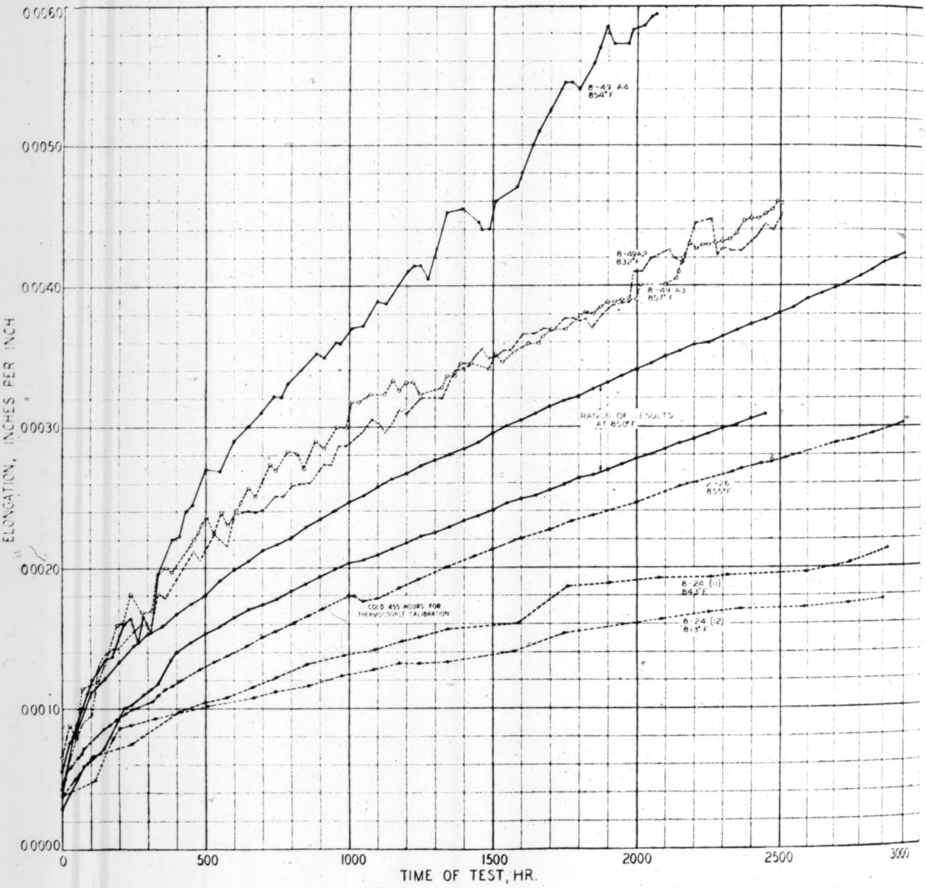

FIG. 3.—Time-Elongation Curves Obtained by Cooperarting Laboratories at Temperatures Other than 850 F. on Steel K20 Under a Stress of 7500 lb. per sq. in.

The creep rates, as determined by the tangent to the curve at the designated time periods, are given in Table IV. The rates are expressed in millionths of an inch per inch per hour. As in the case of the deformation values, differences exist in the results from the various laboratories at each of the time periods considered. As before, however, the agreement is believed to be good, especially when consideration is given to the sensitivity of the creep resistance and the magnitude of the values considered.

TABLE V.—TOTAL DEFORMATION (ELASTIC PLUS PLASTIC) OBTAINED BY COOPERATING LABORATORIES AT TEMPERATURES OTHER THAN 850 F.

Steel K20 (0.35 per cent Carbon), 7500 lb. per sq. in. Stress

Laboratory and Specimen Designation	Temperature, deg. Fahr. at *Co*	Total Deformation at Indicated Time Period, per cent								
		0	250 hr.	500 hr.	750 hr.	1000 hr.	1500 hr.	2000 hr.	2500 hr.	3000 hr.
2-26[a]	855	0.037	0.099	0.129	0.154	0.179	0.212[c]	0.247[c]	0.277[c]	0.325[c]
8-24 (11)[b]	843	0.037	0.078	0.104	0.121	0.138	0.164	0.190	0.197	0.210
8-24 (12)[b]	813	0.037	0.088	0.100	0.111	0.122	0.142	0.160	0.172	0.177
8-49 (A2)[b]	832	0.045	0.154	0.213	0.250	0.288	0.350	0.410	0.449	.....
8-49 (A3)[b]	857	0.065	0.167	0.235	0.271	0.310	0.350	0.390	0.460	.....
8-49 (A4)[a]	854	0.037	0.156	0.270	0.321	0.367	0.450	0.584	.....	.....
Average of 850 F. tests		0.037	0.131	0.168	0.203	0.230	0.276	0.316	0.359	0.407

NOTE: 49A2, Non-inductive furnace, 18-8 sleeve.
49A3, Inductive furnace, silver sleeve.
49A4, Non-inductive furnace, silver sleeve.

[a] Temperature distribution in conformance with A.S.T.M. Methods.

[b] Temperature distribution not in conformance with A.S.T.M. Methods.

[c] Values somewhat low due to discontinuity in test at 1000 hr.

8-24 (11), 8-24 (12) } Calibration established at 800 F.
8-49 (A2)—839 ± 6 F.
8-49 (A3)—858 ± 7 F.

TABLE VI.—CREEP RATES OBTAINED BY COOPERATING LABORATORIES AT TEMPERATURES OTHER THAN 850 F.

Steel K20 (0.35 per cent Carbon), 7500 lb. per sq. in. Stress

Laboratory and Specimen Designation	Temperature, deg. Fahr. at *Co*	Creep Rate at Indicated Time Period, millionth in. per inch per hr.							
		250 hr.	500 hr.	750 hr.	1000 hr.	1500 hr.	2000 hr.	2500 hr.	3000 hr.
2-26[a]	855	1.41	1.16	1.00	0.98	0.77	0.61	0.54	0.44
8-24 (11)[b]	843	1.33	0.74	0.68	0.53	0.57	0.22	0.20	0.32
8-24 (12)[b]	813	0.56	0.45	0.44	0.40	0.37	0.30	0.16	0.14
8-49 (A2)[b]	832	1.80	1.90	1.28	1.62	1.00	0.92	0.92	....
8-49 (A3)[b]	857	3.15	1.94	1.40	1.50	1.00	1.10	1.10	....
8-49 (A4)[a]	854	3.40	3.00	2.18	1.95	1.95	1.60	....	....
Average of 850 F. tests		1.98	1.42	1.13	0.99	0.82	0.80	0.76	0.73

NOTE: 49A2, Non-inductive furnace, 18-8 sleeve.
49A3, Inductive furnace, silver sleeve.
49A4, Non-inductive furnace, silver sleeve.

[a] Temperature distribution in conformance with A.S.T.M. Methods.

[b] Temperature distribution not in conformance with A.S.T.M. Methods.

[c] Values somewhat low due to discontinuity in test at 1000 hr.

8-24 (11), 8-24 (12) } Calibration established at 800 F.
8-49 (A2)—839 ± 6 F.
8-49 (A3)—858 ± 7 F.

Laboratory 3 conducted duplicate tests using identical equipment in both cases. The agreement obtained was good, although the differences existing in both the deformation and creep rates were of the same order of magnitude as those between certain of the other laboratories in which different type equipment was used.

Laboratory 4 likewise conducted two tests, one with its original extensometers and the other after improvements had been made. These improvements consisted in the substitution of rigid alloy steel arms for the flexible platinum strips first used. The time-elongation curves obtained with both types of extensometers are given in Fig. 2 and it is apparent that the change made has resulted in a smoother curve. The creep rates and the deformation in the two tests are, however, of the same order of magnitude, although the differences which do exist are of a higher magnitude than those obtained by certain of the other laboratories.

Tests Not at the Specified Temperature of 850 F.:

Certain of the tests by laboratories 2 and 8 were conducted at temperatures either above or below 850 F. by an amount greater than that permitted by A.S.T.M. methods for the specified temperature. The time-elongation curves from these tests are shown in Fig. 3. For comparative purposes, the range in the 850 F. test results are likewise included.

Table V gives the total deformation values for these tests at certain specified time periods, while Table VI gives the creep rates, as determined by the tangent to the curves, at these same time periods.

Two of the tests, 8-24(11) and 8-24(12), were conducted at temperatures below that specified and it is not surprising, therefore, that the deformation and creep rate values obtained fall below the range of values reported by the other laboratories.

However, one of the tests conducted at a temperature above 850 F., 2-26, gave values which, in general, fall below the range obtained by the other laboratories at 850 F. This is an unexpected circumstance and is even more surprising because the equipment used was similar to that employed by laboratory 2 in its other test, the results from which fall toward the high side of both the deformation and creep ranges.

Likewise, one test, 8-49(A2), which was conducted at 832 F., yielded results considerably above the average obtained from the 850 F. tests. The lack of agreement becomes even more pronounced when it is noted that the results from this test agree closely with those from a test at 857 F., 8-49(A3), while a test conducted at 854 F., 8-49(A4), yielded both deformation and creep rate

TABLE VII.—DETAILS OF THE SPECIMEN AND EXTENSOMETER SYSTEM USED BY THE COOPERATING LABORATORIES.

Laboratory	Diameter, in.	Gage Length, in.	Attached to Adaptors by	Type Extensometer	Smallest Reading, millionths in. per inch
LABORATORIES IN WHICH TESTS WERE CONDUCTED AT 850 F.					
No. 1	0.505	2.3	Screw threads	Microscope Platinum strips	21.7
No. 2-14	0.375	12.0	[a]	Dial	0.83
No. 3	0.505	2.3	Screw threads	Double telescope 2 reference points	25.0
No. 4	0.505	2.3	Screw threads	Microscope Rigid steel arms	21.7
No. 5	0.505	2.0	Screw threads	Double telescope 2 reference points	20.0
No. 6	0.505	10.0	[a]	Double telescope 2 reference points	4.0
No. 7	0.505	2.0	Screw threads	Mirrors	2.8
LABORATORIES IN WHICH TESTS WERE CONDUCTED AT TEMPERATURES OTHER THAN 850 F.					
No. 2-26	0.375	20.0	[a]	Dial	5.0
No. 8	0.505	2.3	Screw threads	Microscope Platinum strips	21.7

[a] No adaptors used, specimens extend beyond ends of furnace.

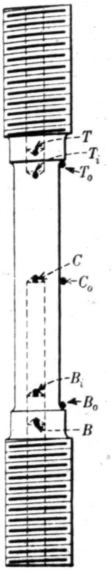

TABLE VIII.—TEMPERATURE DISTRIBUTION EXISTING IN THE CREEP FURNACES OF THE COOPERATING LABORATORIES WHOSE TESTS WERE IN CONFORMANCE WITH THE CODE AT 850 F.

	NOMINAL TEST TEMPERATURE, DEG. FAHR.									
	1	2 14A	3(a)	3(b)	4	5	6	7		
T	832				850±1					
T_i	847									
T_o		848.8	848	852		850±2	850±1	849		
C	850		848	850	850±1					
C_o	847	851.5	847	849		850±2	850±1	850		
B	847		847	848	850±1					
B_i	850									
B_o	847	848.3	849	850		850±2	850±1	849		

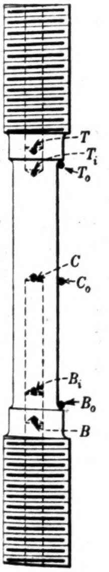

TABLE IX.—TEMPERATURE DISTRIBUTION EXISTING IN THE CREEP FURNACES OF THE COOPERATING LABORATORIES WHOSE TESTS WERE CONDUCTED AT TEMPERATURES OTHER THAN 850 F.

	NOMINAL TEST TEMPERATURE, DEG. FAHR.									
	2-26	8-24(11)*	8-24(12)*	8-49(A2)	8-49(A3)	8-49(A4)				
T		800	800							
T_i		805	805	847	860	853				
T_o	853.7			842**	865**	849**				
C		815	815							
C_o	853.7	830	830	832	857	854				
B		790	790							
B_i		800	800	850	845	850				
B_o	858.3			845**	853**	845**				

* Calibration established at 800 F. rather than at 850 F.

** Location of thermocouples approximately ½ in. outside of gage marks.

values considerably above those of the 857 F. test.

Discussion of Results:

In an attempt to explain the observed differences, attention was given to the various types of equipment employed, as well as to the temperature distribution. These findings are summarized in Tables VII, VIII and IX.

From Table VII it appears that no correlation exists between the type of apparatus and the observed spread in results. For example, laboratories 1 and

2 used equipment of an entirely different type, yet the agreement in their results was very good. On the other hand, laboratories 1 and 4 used nearly identical equipment and the spread existing in their findings was greater than that for the previously two considered laboratories. Likewise, in the two tests reported by laboratory 2 nearly identical equipment was used and an appreciable spread was obtained with the test conducted at the higher temperature giving the lower results.

TABLE X.—CHARACTERISTICS OF FURNACES USED IN COOPERATIVE CREEP TESTS ON STEEL K20 AT 850 F., 7500 LB. PER SQ. IN. STRESS.

Laboratory Designation	Type Furnace	Type Current	Voltage	Amperage		Tube		Number of Turns	Holders	How Wound
				On	Off	Length, in.	Diameter, in.			
1............	Vertical	a.c.	80 to 100	5.5	3.8	15	1¾	104	Non-magnetic	Inductive
2 (14A)......	Horizontal	a.c.	110	10.8	7.0	..	..	3[a]	[b]	Inductive
2 (26).......	Vertical	a.c.	110	43	0	..	..	6[a]	[b]	Non-inductive
3............	Vertical	a.c.	110	7.5	5.0	..	..	45	Non-magnetic	Inductive
4............	Vertical	a.c.	45 to 39	5.0	4.4	15	2	94	Non-magnetic	Non-inductive
5............	Vertical	a.c.	110	2.5-9	...	12	3	60	Non-magnetic	Inductive
6............	Vertical	a.c.	220	4.0	...	..	..	120	[b]	Inductive
7............	Vertical	a.c.	220	7.0	...	12	3½	70	Non-magnetic	Inductive
8-24.........	Vertical	a.c.	110	7.0	...	12	1⅜	54	Non-magnetic	Inductive
8-49 (A2)....	Vertical	a.c.	110	...	...	..	..	52	Non-magnetic	Non-inductive
8-49 (A3)....	Vertical	a.c.	110	...	...	..	..	...	Magnetic	Inductive
8-49 (A4)....	Vertical	a.c.	110	...	...	..	..	...	Non-magnetic	Non-inductive

[a] Number of furnace windings.

[b] Specimen extends outside of furnace.

NOTE.—The term "non-magnetic" is purely relative and generally implies that this was the case when the holders were first installed.

Neither do temperature variations account for the observed differences in the tests which were conducted at 850 F. or in two of the tests at the other temperatures. The low values reported from two of the tests by laboratory 8 may, however, be due to the fact that the temperature employed in these tests was low.

During the course of these tests the question arose as to the possible influence of magnetic vibrations produced in those furnaces which were wound inductively. A survey was made of the electrical characteristics of the furnaces employed in these tests and the results obtained are summarized in Table X. This table shows that all of the laboratories used alternating current and that in all but a few cases furnaces were wound inductively.

In order to obtain further evidence on this subject, laboratory 8 undertook a series of tests using both inductive and non-inductive wound furnaces as well as magnetic and non-magnetic holders. The time-elongation curves obtained are included in Fig. 3.

These findings definitely indicate that the possible magnetic vibrations produced in inductively wound furnaces do not increase the deformation or creep rate. This is also in keeping with the experiences of laboratories 2 and 6.

Conclusions:

The data submitted permit the following conclusions:

1. The K20 steel used was of at least as high a degree of uniformity as it is possible to secure commercially under the present knowledge of melting practice and the results obtained from the tests at 850 F. are in very good agreement when the comparisons are based on creep strength.

2. The validity of this conclusion is substantiated when it is observed that

the range in creep stress (based on the fact that creep varies as the 3.33 power of the stress), with the largest creep rate assigned to the 7500-lb. stress, is from 7500 to 8050 lb. per sq. in. for those tests which were conducted at 850 F. The relative strengths, therefore, range from 1.00 to 1.074.

3. It is interesting to note that in the report of Committee III-D,[1] the relative tensile strength values for this same steel at 850 F. ranged from 1.0 to 1.10 for those tests conducted at 850 F. In other words, the agreement in creep strength is of the same order of magnitude as that found to exist in the tensile strength values.

4. If these same results are compared on the basis of creep rate rather than creep strength, then appreciable differences do exist which cannot be directly related to the type equipment used, the size of specimen, the type extensometer, the temperature distribution on the specimen or to the electrical characteristics of the furnace.

5. The results therefore indicate that the creep rate and deformation characteristics are too sensitive an index of strength to permit exact duplication either in different laboratories or in duplicate tests in the same laboratory.

6. The results obtained from certain of the tests at temperatures other than 850 F. are not in as good agreement either among themselves or with the results obtained from the 850 F. tests.

7. These apparent discrepancies may be due either to slight non-uniformities in the steel or to as yet unknown inconsistencies in the testing technique. Additional work is planned in order that these differences may be more fully explained.

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[1] A full description of this material is given in "Short-Time Tensile Tests at 850 F. of the 0.40 per cent Carbon Steel, Material K-20," Report of Subgroup D of Subcommittee 3, *Transactions*, Am. Soc. Mechanical Engrs., February, 1936, pp. 97–101.

DISCUSSION

MR. H. C. CROSS[1] (*presented in written form*).—Figure 3 of Appendix III contains time-elongation curves for tests made by laboratory 8 on test specimens cut from bar 49A. These tests were not run at 850 F. as were the tests by most of the cooperating laboratories. The temperature distribution in several of the furnaces used did not meet the requirements of the A.S.T.M. Method E 22 – 35 T.

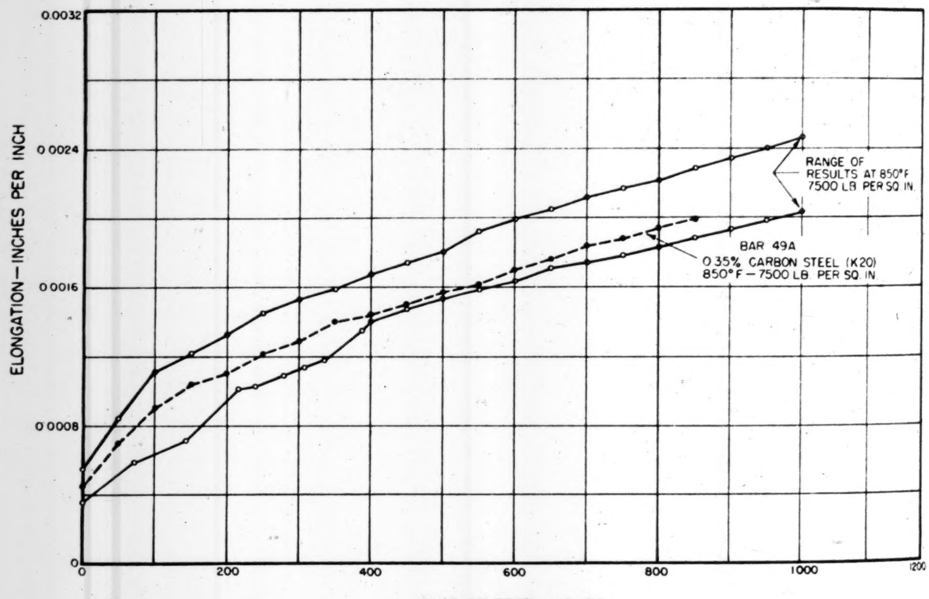

FIG. 1.—Comparison of Time-Elongation Curve for Bar 49A and Range of Cooperators' Results at 850 F. and 7500 lb. per sq. in. for 0.35 per cent Carbon Steel (K20).

These time-elongation curves on bar 49A neither check the results of the cooperating laboratories nor check each other. Since no other laboratory made tests on bar 49A, these tests indicated a possibility of lack of uniformity in bar 49A and a lack of similarity with the other bars of K20 steel tested.

As a check on this possibility, the remainder of bar 49A was obtained from laboratory 8. A creep test specimen from bar 49A was tested at 850 F. and 7500 lb. per sq. in. in a furnace which in a calibration for temperature distribution met fully the requirements of Method E 22 – 35 T.

The time-elongation curve obtained is shown in the accompanying Fig. 1. Also plotted in Fig. 1 is the range of results obtained by those cooperating laboratories that conducted their tests in conformance with the method and at 850 F. The time-elongation curve falls within this range and, as shown in the accompanying Table I, the creep rates and total deformation for this bar 49A agree very closely with the averages listed in Appendix III.

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[1] Metallurgist, Battelle Memorial Institute, Columbus, Ohio.

TABLE I.—TOTAL DEFORMATIONS AND CREEP RATES AT DESIGNATED TIME PERIODS FOR K20 (0.35 PER CENT CARBON STEEL) AT 850 F. AND 7500 LB. PER SQ. IN.

	0 hr.	250 hr.	500 hr.	750 hr.
TOTAL DEFORMATION, PER CENT				
Average—Appendix III.....	0.037	0.131	0.168	0.203
Bar 49A..................	0.045	0.120	0.158	0.185
CREEP RATE, MILLIONTH IN. PER INCH PER HOUR				
Average—Appendix III.....	.....	1.98	1.42	1.13
Bar 49A..................	.....	1.85	1.30	1.10

It is therefore indicated that the lack of agreement of the time-elongation curves for bar 49A supplied by laboratory 8 is not due to nonuniformity of bar 49A as compared with other bars of K20 steel tested. These widely differing results in Fig. 3 of Appendix III for bar 49A should therefore not be allowed to discredit the indication given by the other results that carefully controlled test conditions produce comparable creep results on a uniform material.

APPENDIX IV

REPORT ON ACCEPTABILITY TESTS FOR HIGH-TEMPERATURE CHARACTERISTICS

(PROJECT NO. 17)

PREPARED BY A. E. WHITE AND C. L. CLARK

Introduction:

It is fully appreciated that time is an important variable in the determination of the high-temperature characteristics of materials and that as long a testing time period as feasible should be used in determining the high-temperature properties.

When the characteristics of a given steel from a given heat have been determined, however, it is likewise important to know whether similar steels from other heats also possess these same characteristics. It would be desirable to employ extended-testing-time periods for this purpose but in general this is not practicable. A need does therefore exist for a relatively short-time test that will serve as an indicator of the high-temperature characteristics.

The present report is concerned with one possible test of this type, namely, stress-rupture tests of approximately 15 hr. duration.

TABLE I.—DESCRIPTION OF STEELS INVESTIGATED.

Steel Designation	Source	Type of Melting Furnace	Heat Treatment, deg. Fahr.	Chemical Composition, per cent							Brinell Hardness	McQuai- Ehn Grai Size
				Carbon	Manganese	Silicon	Chromium	Molybdenum	Sulfur	Phosphorus		
K20	Bethlehem	Open Hearth	[b]	0.35	0.55	0.19	....	....	0.030	0.016	129	.....
1040	Timken	Open Hearth	Annealed 1550	0.43	0.68	0.20	....	....	0.033	0.035	167	4 to 5
0.50 Mo	Committee[a]	Open Hearth	Drawn 1350	0.146	0.54	0.21	....	0.53	0.018	0.015	121	.....
4 to 6 Cr+Mo	Committee[a]	Electric Arc	Annealed 1525	0.092	0.43	0.21	4.79	0.51	0.016	0.010	126	.....
4 to 6 Cr+Mo(A)	Timken	Electric Arc	Annealed 1550	0.10	0.45	0.18	5.09	0.55	0.017	0.015	126	7

[a] Made by Crucible Steel Co. and fabricated into tubes by The Babcock & Wilcox Co.

[b] Heat treatment consisted of following steps:

1. Heated to 1550 F. in 2 hr., held 1 hr. and furnace cooled to 1000 F., from which temperature the bars were air cooled.
2. Reheated to 1280 F. in 4 hr., held 2 hr. and furnace cooled to 1000 F., then air cooled.
3. After straightening bars, heated to 950 F. and air cooled.
4. Bars again reheated to 950 F. and air cooled.

Procedure:

Descriptions of the equipment and procedure employed have been published in the literature and will not be repeated in detail.[1] The test is relatively simple and consists of fracturing a series of specimens at each temperature under fixed loads so adjusted that the resulting fracture times vary from a few minutes up to 15 hr. For tests of this duration a standard type tension machine is used.

It has been found that when the stresses and corresponding fracture times are plotted to logarithmic coordinates, a straight-line relationship exists provided the material possesses a sufficient degree of structural and surface stability under the given test conditions. It is thus possible to obtain the stresses corresponding to definite fracture times.

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[1] A. E. White, C. L. Clark and R. L. Wilson: "The Fracture of Carbon Steels at Elevated Temperatures," *Transactions*, Am. Soc. Metals, Vol. 25, p. 863 (1937).
A. E. White, C. L. Clark and W. G. Hildorf: "Stress Rupture Tests for Heated Metal," *Metal Progress* March, 1938, p. 266.

TABLE II.—STRESS-RUPTURE CHARACTERISTICS.

Temperature, deg. Fahr.	Stress, lb. per sq. in.	Rupture Time, hr.[a]	Elongation in 2 in., per cent	Reduction of Area, per cent
K20 (0.37 PER CENT CARBON) STEEL				
650	65 500	S.T.T.S.	45.5	69.7
	63 000	0.465	45.0	67.5
	60 000	1.18	45.5	67.7
750	55 500	S.T.T.S.	49.0	76.8
	51 000	0.483	49.5	74.5
	49 000	1.22	52.5	75.6
	45 000	6.33	52.5	75.3
	43 000	10.33	55.5	78.9
	42 000	21.60	55.5	76.6
850	45 050	S.T.T.S.	52.5	79.5
	40 000	0.40	56.0	79.5
	36 000	1.67	56.0	79.5
	32 500	8.30	57.5	79.2
	31 000	13.92	53.0	78.4
1000	30 500	S.T.T.S.	58.5	75.4
	25 500	0.62	71.5	84.3
	23 000	1.23	76.5	85.6
	19 000	6.95	79.0	84.3
	17 000	13.10	78.5	84.3
S.A.E. No. 1040 STEEL				
650	78 750	S.T.T.S.	42.0	70.8
	76 250	0.133	40.5	68.4
	70 000	7.46	42.5	67.5
750	67 200	S.T.T.S.	47.0	76.4
	63 000	0.313	40.0	74.7
	60 000	1.47	52.5	76.0
	57 500	3.97	40.5	74.1
	55 000	12.07	49.0	76.2
850	56 350	S.T.T.S.	47.0	78.4
	50 000	0.313	49.5	79.8
	45 000	2.30	48.0	78.4
	40 000	16.47	56.5	77.2
1000	38 250	S.T.T.S.	59.0	83.8
	32 500	0.47	56.0	79.5
	30 000	1.15	53.5	78.4
	26 000	4.05	69.0	78.4
	23 000	10.00	64.5	79.0
0.50 PER CENT MOLYBDENUM STEEL				
900	51 500	S.T.T.S.	32.0	75.1
	50 000	N.F.	19.0	20.2 (discontinued at 15 hr.)
1000	46 000	S.T.T.S.	37.5	79.2
	44 000	0.08	36.0	78.8
	43 000	1.30	40.0	79.5
	42 000	2.17	42.5	79.2
	40 500	18.88	41.4	72.7
	39 500	N.F.	19.0	16.6 (discontinued at 15 hr.)
1100	37 800	S.T.T.S.	47.0	84.3
	33 000	0.43	53.0	84.3
	31 000	1.37	60.5	84.0
	29 000	3.78	63.0	81.8
	27 000	10.13	60.0	80.0
1200	27 250	S.T.T.S.	71.0	89.3
	22 000	0.53	64.5	88.5
	19 000	1.80	76.0	89.2
	16 500	5.16	80.5	89.2
	14 250	13.58	91.0	90.2
4 TO 6 PER CENT CHROMIUM-MOLYBDENUM STEEL				
800	47 250	S.T.T.S.	34.0	77.4
	46 500	5.20	45.0	79.2
	46 000	3.42	42.0	80.2
	45 000	7.53	41.0	80.2
	44 500	8.00	44.0	78.3
900	43 850	S.T.T.S.	39.0	80.7
	41 500	0.45	44.0	80.0
	40 000	1.25	43.5	79.0
	38 500	2.77	53.0	81.8
	36 000	9.95	49.0	81.9
1000	37 250	S.T.T.S.	45.5	83.4
	34 500	0.55	49.0	82.2
	32 000	1.31	61.0	84.2
	30 000	3.20	61.5	84.2
	26 500	12.00	62.0	82.1
1100	29 875	S.T.T.S.	56.5	89.0
	25 000	0.73	69.5	88.8
	23 000	1.38	67.0	88.0
	20 000	4.90	84.0	91.3
	17 500	15.73	104.5	91.3

[a] S.T.T.S. = Short-time tensile strength at indicated temperatures.
N.F. = Not fractured during testing time period.

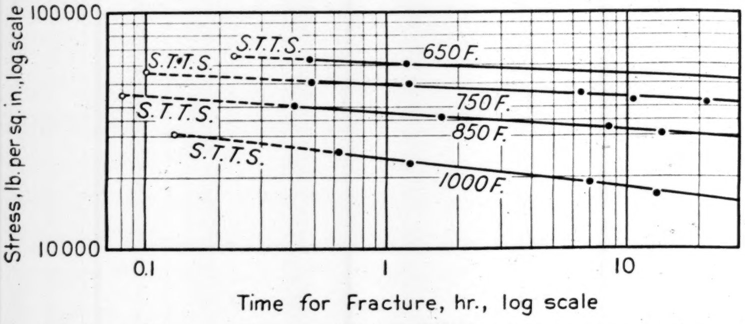

FIG. 1.—Stress-Rupture Characteristics of K20 Steel (0.37 per cent Carbon).
S.T.T.S. = Short-time tensile strength at indicated temperatures.

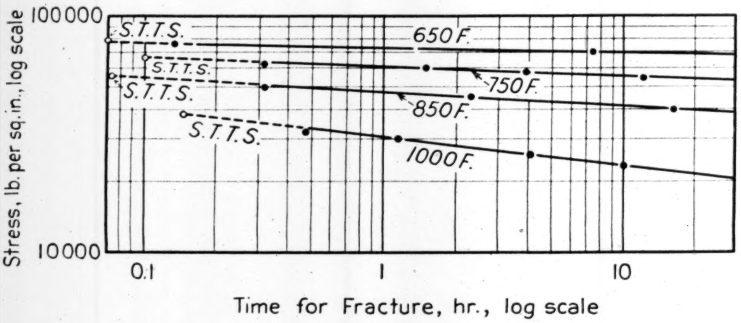

FIG. 2.—Stress-Rupture Characteristics of S.A.E. No. 1040 Steel.
S.T.T.S. = Short-time tensile strength at indicated temperatures.

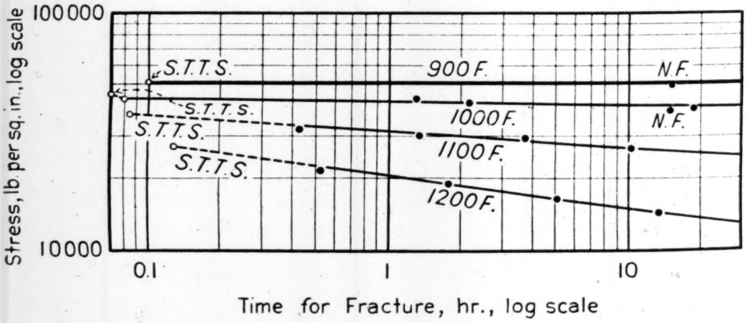

FIG. 3.—Stress-Rupture Characteristics of 0.50 per cent Molybdenum Steel.
S.T.T.S. = Short-time tensile strength at indicated temperatures.

Steels Investigated:

Available information with respect to the five steels under consideration is given in Table I. Two of the steels were of the plain carbon type, two of the 4 to 6 per cent chromium plus molybdenum type, and one of the 0.50 per cent molybdenum type. The two steels designated as committee steels were received in the form of seamless tubes of $4\frac{1}{2}$ in. outside diameter with a $\frac{7}{8}$-in. wall. These steels are the ones that are also being subjected to tubular expansion,[1] torsional creep and tensile creep tests. The remaining three steels were in the form of one inch round bars.

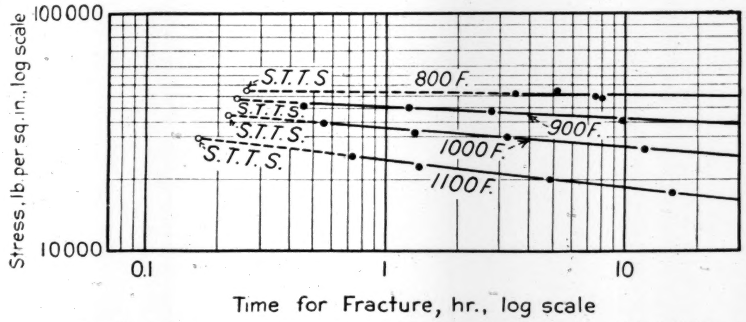

FIG. 4.—Stress-Rupture Characteristics of 4 to 6 per cent Chromium-Molybdenum Steel. S.T.T.S. = Short-time tensile strength at indicated temperatures.

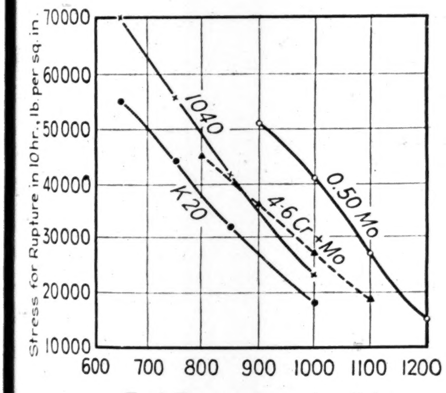

FIG. 5.—Stress for Rupture in 10 hr. *versus* Temperature for Four Indicated Steels.

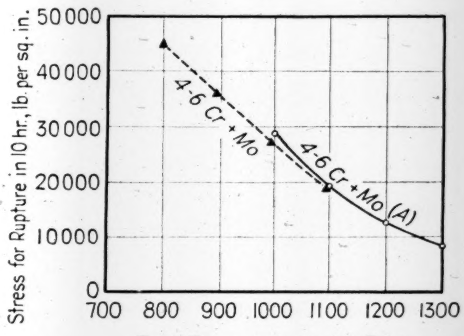

FIG. 6.—Comparative Stress-Rupture Characteristics of Two 4 to 6 per cent Chromium-Molybdenum Steels.

Test Results:

The results obtained from the stress-rupture tests are given in Table II, and the stresses and corresponding fracture times are plotted to logarithmic coordinates in Figs. 1 to 4. In the case of the two carbon steels, K20 and 1040, temperatures of 650, 750, 850, and 1000 F. were employed, while the temperatures for the 0.50 per cent molybdenum steel were 900, 1000, 1100, and 1200 F., and for the chromium-molybdenum steel, 800, 900, 1000, and 1100 F.

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[1] See Appendix I, p. 118.

It was originally intended that these tests would be conducted on the 0.50 per cent molybdenum steel at 800 F. It was found, however, as indicated in Fig. 3, that this steel was very susceptible to strain hardening at 900 F. as evidenced by the fact that a stress only slightly below the tensile strength did not produce fracture in 15 hr. It follows, therefore, that at lower temperatures this same condition would continue to exist and the logarithmic line, expressing the relationship between stress and fracture time, will be nearly parallel to the time axis.

In this same connection, it is interesting to note that the 0.50 per cent molybdenum steel is more susceptible to strain hardening at 900 F. than is either of the carbon steels at 650 F. or the chromium-molybdenum steel at 800 F.

Figure 5 compares the stresses required for fracture in 10 hr., as obtained from the logarithmic charts, for each of the steels over the temperature range considered. First comparing the two carbon steels it will be noted that the 1040 steel requires a greater stress for fracture at each of the temperatures than the K20 steel. Likewise the 0.50 per cent molybdenum steel is superior to the chromium-molybdenum steel at each of the temperatures, although the difference between the two decreases with increasing temperature.

The creep characteristics of all of these steels are not as yet available for comparison with the stress-rupture characteristics. They are, however, available at certain of the temperatures for the 1040 and K20 steels. These values, based on tests of 1000 hr. duration, are as follows:

		Stress for Designated Creep Rate	
Steel Designation	Temperature, deg. Fahr.	0.01 per cent per 1000 hr.	0.10 per cent per 1000 hr.
K20	850	3100	7400
1040	800	13000	18500
1040	1000	2800	5550
1040	1200	140	860

The 1040 steel is nearly as strong at 1000 F. as the K20 steel is at 850 F. and the stress-rupture test results are therefore in keeping with those from the creep tests.

Stress-rupture tests were likewise conducted on a second heat of the chromium-molybdenum steel, designated as 4 to 6 Cr + Mo(A), and these results are compared with those from the first heat in Fig. 6. It will be noted that the stress-rupture characteristics of these two heats are nearly identical. Creep characteristics are available from the second heat but not from the first. Those for the second heat are as follows:

		Stress for Designated Creep Rate	
Steel Designation	Temperature, deg. Fahr.	0.01 per cent per 1000 hr.	0.10 per cent per 1000 hr.
4 to 6 Cr+Mo(A)	900	11 500	15 250
4 to 6 Cr+Mo(A)	1000	7 600	10 100
4 to 6 Cr+Mo(A)	1100	3 200	5 850
4 to 6 Cr+Mo(A)	1200	1 700	2 800

Since the stress-rupture characteristics of these two chromium-molybdenum steels are in such good agreement it is predicted that the creep properties of the first heat, when they are available, will be very similar to those given for the second heat of this steel.

Table II likewise gives the ductility characteristics of the fracture specimens. For the time periods considered in these tests these values are not of as great importance as when the tests are continued for several thousand hours. In nearly every case the ductility was increased as the time for fracture was extended.

DISCUSSION

Mr. H. W. Gillett[1] (*presented in written form*).—It would have been interesting to have had more tests of the 0.50 per cent molybdenum steel at 900 F., to bring out whether the assumption of an extremely high degree of strain hardening is justified, or whether it merely happened that the bar tested at 50,000 lb. per sq. in. was stronger than the one that broke at 51,500 lb. per sq. in. A 3 per cent variation in tensile strength between duplicate bars is not unusual. It will be noted in Fig. 3 that in the tests at 1000 F. another bar of this steel is out of line.

It would be of interest to have recorded what the true austenitic grain size of the Timken 1040 steel is. Only the McQuaid-Ehn grain size is given.

One wonders how far one may trust the assumption that because the stress-rupture properties of two steels are alike, as shown by the behavior in 15-hr. tests, the whole long-time high-temperature behavior will be alike. Can it be argued that any two steels that behave alike under these overstress conditions will necessarily be alike under design stresses? Should not the chemical composition, metallographic structure, austenitic grain size, and coarsening characteristics be required to be identical, as well as the stress-rupture curves?

The authors compare the creep behavior of Timken 1040 steel at 1000 F. with K20 at 850 F., but the stress-rupture curves for the two steels at those temperatures do not coincide. On the other hand the stress-rupture curves for K20 at 1000 F. and for 5 per cent chromium, 0.5 per cent molybdenum steel at 1100 F. do coincide, and the creep figures are of the same order. The lower end of the stress rupture curves for 5 per cent chromium, 0.5 per cent molybdenum steel at 1000 F. and for carbon-molybdenum steel at 1100 F., coincide. Does this mean that the creep for the chromium-molybdenum steel at 1000 F. and the carbon-molybdenum steel at 1100 F. will be similar? Or do the authors confine their expectance of similarity in creep behavior, on the basis of like stress-rupture tests, to steels of like composition at the *same* temperature?

Do the authors find it sufficient to make stress-rupture tests at one temperature to establish identity or differences, or should the curves for each steel at two or more temperatures coincide before one can rely on identity?

Messrs. A. E. White[2] **and C. L. Clark**[2] (*authors' closure*).—The authors appreciate Mr. Gillett's comments and shall attempt to answer the questions in the order in which they were raised.

It is true that only two tests were conducted on the 0.50 per cent molybdenum steel at 900 F. but the conclusion drawn with respect to strain hardening is believed to be justified on the basis of the change in slope of the logarithmic line with temperature, as well as by the authors' experience with steels of this type at 900 and 925 F.

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[1] Metallurgist, Battelle Memorial Institute, Columbus, Ohio.

[2] Director, and Research Engineer, respectively, Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

As stated in the introduction, the present test is extended as a means of determining whether or not steels from different heats will possess the same high-temperature characteristics as a heat previously subjected to long-time tests. By this statement it was intended to imply that steels of the same chemical composition and heat treatment were to be considered. It may later develop that steels of different types can be compared, as Mr. Gillett has attempted to do, but more information will first have to be obtained. In other words, for the present, it is believed that steels of like composition should be compared at the same temperature.

In regard to the number of temperatures at which the comparisons are to be made, it was intended that these should be confined to the proposed operating temperature, or temperature range. It is entirely possible that the relative merit of two steels may change depending on whether the test temperature is such that the strain hardening rate, or recrystallization rate, predominates. In general, however, an operating temperature for any given application will not vary sufficiently to encounter these two different fields.

APPENDIX V

PROGRESS REPORT ON STUDY OF EFFECTS OF MANUFACTURING VARIABLES ON THE CREEP RESISTANCE OF STEELS

(Project No. 18)

Prepared by Howard C. Cross and J. G. Lowther

Synopsis

This progress report shows results of creep tests at 850 F. on twelve plain carbon steels with known aluminum additions and one carbon-vanadium steel. Some of the steels were tested at 750 and 950 F.

Some of the steels were intentionally coarsened by proper heat treatments to provide material for comparison of the relative creep resistance of fine-grained and coarse-grained materials.

The data indicate decided superiority of creep resistance at 750, 850 and 950 F. for coarse-grained plain carbon steel over fine-grained plain carbon steel of the same chemical composition. Several relaxation tests on K20 also indicate superiority for coarsened K20 steel.

The carbon-vanadium steel which showed superior creep resistance to plain carbon steel as fine-grained was not improved greatly by coarsening.

Introduction

In the literature are creep test data which show wide discrepancies in the load-carrying abilities of carbon steels at 850 F. Such data have been collected and discussed by Gillett.[1] It was pointed out that available test data indicate superior creep resistance for killed carbon steels as compared with rimming or semi-killed steels.

Data obtained from many sources indicated a wide variation in properties between various killed steels made using different melting practices. For some of these data, the better creep resistance was shown by those steels showing the larger grain size in the McQuaid-Ehn test.

Clark and White[2] comment that electric-arc melted steel appears more creep resistant than basic open-hearth steel, also that induction-melted steel may be more resistant than arc-melted steel, qualifying these statements by pointing out that melting practice may differ even with the use of the same melting medium. They also comment that ingot size and degree of reduction in hot-working may be important variables.

Jenkins, Tapsell, Mellor, and Johnson[3] studied two series of steels, a low-carbon series (0.13 to 0.20 per cent) and a medium-carbon series (0.37 to 0.42 per cent). Some were electric-melted and some were open-hearth melted. Of the twelve steels tested, one in each series showed poor creep resistance, for which there seemed to be no explanation. One of the poor steels was melted in the electric furnace, indicating a need for the qualifying comments made by Clark and White as regards electric *versus* open-hearth steels. The creep resistance of one of the poor steels was improved by a grain coarsening treatment, but the second poor steel was not improved.

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[1] H. W. Gillett, "Discrepancies in the Load-Carrying Abilities of Carbon Steels at 850 F.," *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 187 (1937).

[2] C. L. Clark and A. E. White, "The Properties of Metals at Elevated Temperatures," *Engineering Research Bulletin No. 27*, University of Michigan, March, 1936.

[3] C. H. M. Jenkins, H. J. Tapsell, G. A. Mellor, and A. E. Johnson, "Some Aspects of the Behavior of Carbon and Molybdenum Steels at High Temperatures," *Transactions*, Chemical Engineering Congress of the World Power Conference (London), Vol. 1, p. 122 (1936).

No statement is made as to actual grain size in the coarsened condition, nor from the single micrographs shown after normalizing without coarsening can any difference in grain-coarsening propensities be traced. It is stated that McQuaid-Ehn tests "showed no abnormality." The statement is also made that no differences in grain size were noted that would account for the high creep rates.

TABLE I.—CHEMICAL COMPOSITION OF THE STEELS USED IN THE CREEP TESTS.

Steel Designation	Chemical Composition, per cent						Aluminum Addition, per cent	Process	McQuaid-Ehn Grain Size
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Vanadium			
K20..........	0.35	0.55	0.016	0.030	0.19	....	0.06 (ladle)	Basic O.H.	7 to 8 (fine)
F............	0.37	0.61	0.016	0.023	0.24	....	0.04	Basic O.H.	6 to 8 (fine)
LF...........	0.27	0.63	0.013	0.035	0.18	....	0.022 (ladle)	Basic O.H.	2 to 4 (coarse)
2807.........	0.28	0.67	0.010	0.044	0.33	....	0	Induction[a]	
2809.........	0.29	0.68	0.011	0.045	0.32	....	0.025	Induction[a]	
2810.........	0.28	0.62	0.011	0.041	0.31	....	0.05	Induction[a]	
15...........	0.58	0.86	0.014	0.024	0.14	....	0	Basic O.H.	1 to 2
18...........	0.58	0.86	0.014	0.024	0.14	....	0.05	Basic O.H.	5 to 6
61...........	0.52	0.75	0.020	0.026	0.22	....	0.025	Basic O.H.	2 to 4
54...........	0.49	0.76	0.017	0.028	0.20	....	0.025	Basic O.H.	2 to 4
56...........	0.51	0.75	0.018	0.033	0.21	....	0.10	Basic O.H.	5 to 7
52...........	0.46	0.54	0.016	0.030	0.23	....	0.105	Basic O.H.	5 to 7
S393.........	0.37	0.70	....	....	0.16	0.18	....	....	8

[a] 65-lb. melt, silica crucible.

The wide discrepancies noted both here and in England in behavior of different lots of steel cannot be explained by the assumption that the steels are really alike but the test data differ due to variations in laboratory technique in creep testing in the various laboratories. The English data were all obtained at the National Physical Laboratory, presumably with the same technique in all cases. As to the American data, the cooperative work on creep testing of steel K20 (0.35 per cent carbon), reported in Appendix II, is sufficient to show that those laboratories that conduct their creep tests strictly in accordance with the A.S.T.M. Tentative Test Method E 22 - 34 T would differentiate sharply between the steels shown in the literature to have poor and good creep resistance.

Gillett stated, "The method of melting, the austenitic grain size, and grain-coarsening treatments all seem to bear some relation to high-temperature performance. The behavior of rimmed steel as compared with fully killed steel and the carry-over of creep resistance or its lack in both the cast and the rolled condition both point to the grain-coarsening properties of the steel and to the melting and deoxidation practice which controls them, as worthy of attention in connection with the problem of production of creep-resistant steels."

The steel-making variables that produce a ten-fold variation in creep behavior of killed steels and a hundred-fold variation between killed and rimmed steels, demand attention.

This is a progress report on an experimental study of some of the variables which may produce these large variations in creep resistance between steels prepared with similar melting practice and with the same approximate chemical composition and heat treatment.

STEELS TESTED

The steels used are listed in Table I, along with their chemical composition and some details of manufacture.

Steel K20 is the Joint High Temperature Committee 0.35 per cent carbon steel for which details of manufacture and heat treatment have been previously given.[4] Two forged plain-carbon steels (0.27 and 0.37 per cent carbon) previously studied by Cross and Dahle[5] were used. Three plain-carbon steels of similar chemical composition (2807, 2809, and 2810), which had different aluminum additions, were available at Battelle, and have been used.

Through the courtesy of Messrs. Aborn and Grossman and the United States Steel Corp., bar stock has been made available as taken from a special heat made for experimental purposes. Steel was supplied from each of five successive ingots taken from this same experimental heat but to each of which had been added a different aluminum addition as follows: ingot 15 none, ingot 16 −0.012 per cent, ingot 17−0.025 per cent, ingot 18 −0.05 per cent, ingot 19−0.10 per cent. Steel from ingots 15 and 18 only has so far been tested.

Through the courtesy of Mr. P. E. McKinney and the Bethlehem Steel Co., six medium-carbon steels were supplied, three fine-grained and three coarse-grained. Four of the six steels have been tested. Steels 61 and 54 were coarse-grained and had aluminum additions of 0.025 per cent, while steels 56 and 52 were fine-grained and had aluminum additions of 0.10 and 0.105 per cent, respectively.

Through the courtesy of Mr. Jerome Strauss and the Vanadium Corporation of America, a plain carbon-vanadium steel (No. S393) was supplied for use in the experiments.

The United States Steel Corp., the Bethlehem Steel Co., and the Vanadium Corporation of America gave complete grain-coarsening data for the steels each supplied.

CREEP TEST EQUIPMENT AND PROCEDURE

Descriptions of the creep test equipment and procedure at Battelle Memorial Institute have been previously given, especially in reports to the sponsor societies of the Joint Committee, and will not be repeated here.[6,7]

Throughout the series of creep tests herein reported the requirements of the A.S.T.M. Tentative Method for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 – 35 T)[8] have been met or exceeded.

The 500-hr. tests used herein are, of course, too short for reliable extrapolation to the usual load for "1 per cent creep in 10,000 hr." The purpose was not to make creep determinations, but merely to show up extreme differences in creep propensities. The 500-hr. period chosen for this evaluation corresponds to the 480-hr. period used by Jenkins and co-workers[3] for a similar purpose. While such a short period appears adequate for a preliminary sorting of high-creep from low-creep materials, its use herein is not

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[4] "Short-Time Tensile Tests at 850 F. of the 0.35 per cent Carbon Steel Material K20," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 58, No. 2, p. 97, (RP—58 - 4) (1936).

[5] H. C. Cross and F. B. Dahle, "High-Temperature Properties of Cast and Wrought Carbon Steels from Large Valves for High-Temperature Service," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 58, No. 2, p. 103, (RP—58 - 5) (1936).

[6] H. W. Gillett and H. C. Cross, "Obtaining Reliable Values for Creep of Metals at High Temperatures," *Metals and Alloys*, Vol. 4, July, 1933, pp. 91–98.

[7] H. C. Cross, "High Temperature Tensile, Creep, and Fatigue Properties of Cast and Wrought High and Low Carbon 18 Cr 8 Ni Type Steel from Split Heats," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 56, No. 7, July, 1934, p. 533.

[8] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1291 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1544.

TABLE II.—GRAIN COARSENING CHARACTERISTICS OF THE CARBON AND CARBON-VANADIUM STEELS TESTED.

Steel Designation	Carbon Content, per cent	Type of Test[a]	Heat Treatment Times at Temperature Indicated	Aluminum Addition, per cent	Material Heat Treated at									
					1500 F.	1550 F.	1600 F.	1650 F.	1700 F.	1750 F.	1800 F.	1850 F.	1900 F.	2000 F.
K20	0.35	Grain size	Carburized 8 hr.	0.06	......	......	8	......	8	......	2 to 6	......	2	......
K20	0.35	Charpy impact	Protected[b], 8 hr.	0.06	......	......	23 ft-lb.	......	18 ft-lb.	......	17 ft.-lb.	......	4 ft-lb.	......
F	0.37	Grain size	Carburized 8 hr.	0.04	......	......	7 to 8	......	6	......	2 to 7	......	−1 and 4	......
F	0.37	Charpy impact	Protected,[b] 8 hr.	0.04	......	......	21 ft-lb.	......	21 ft-lb.	......	17 ft-lb.	......	13 ft-lb.	......
LF	0.27	Grain size	Carburized 8 hr.	0.022	......	......	5 to 6	......	2 to 4	......	2	......	−1 and 4	......
LF	0.27	Charpy impact	Protected,[b] 8 hr.	0.022	......	......	28 ft-lb.	......	26 ft-lb.	......	24 f t-lb.	......	22 ft-lb.	......
K20	0.35	Grain size	2 hr., air cooled	0.06	......	......	......	......	......	......	......	......	3 to 4	......
K20	0.35	Grain size	2 hr., A.C., 6 hr., A.C.	0.06	......	......	......	......	......	......	......	......	0 to 3	......
F	0.37	Grain size	2 hr., air cooled	0.04	......	......	......	......	......	......	......	......	−1 to 4	......
LF	0.27	Grain size	2 hr., air cooled	0.022	......	......	......	......	......	......	......	......	1 to 4	......
2807	0.28	Grain size	1 hr., air cooled	0	......	......	......	3 to 7	......	1 to 7	coarse	coarse	......	......
2809	0.29	Grain size	1 hr., air cooled	0.025	......	......	......	8	......	8	med. coarse	coarse	......	......
2810	0.28	Grain size	1 hr., air cooled	0.05	......	......	......	8	......	8	5 to 6 fine 7 to 8	duplex 5 to 8	......	......
15	0.58	Grain size	1 hr., air cooled	0	60% 3 to 4 40% 5 to 6	......	......	90% 3 to 4 10% 1 to 2[d]	......	......	Trace 1 >95% 2 to 3	......	......	......
18	0.58	Grain size	1 hr., air cooled	0.05	100% 6 to 7[c]	......	......	Trace 5 >95% 6	......	......	100% 5 to 6 Rim 0 to −2	......	10% 1 80% 2 to 4[d] 10% 5	......
61	0.52	Grain size	$\frac{3}{4}$ hr., air cooled	0.025	......	75% 2 to 4 25% 5 to 7	90% 2 to 4 10% 5 to 7	100% 2 to 4	......	......	......	......	......	......
54	0.49	Grain size	$\frac{3}{4}$ hr., air cooled	0.025	......	60% 2 to 4 40% 5 to 7	90% 2 to 4 10% 5 to 7	100% 2 to 4	......	......	......	......	......	......
56	0.51	Grain size	$\frac{3}{4}$ hr., air cooled	0.10	......	100% 6 to 8	100% 6 to 8	5% 4 95% 6 to 8	30% 2 to 4 70% 6 to 7	60% 2 to 4 40% 5 to 7	90–100% 2 to 4 10% 5 to 6	100% 2 to 4	......	......
52	0.46	Grain size	$\frac{3}{4}$ hr., air cooled	0.105	......	100% 6 to 8	10% 2 to 4 90% 6 to 8	50% 2 to 4 50% 6 to 8	65% 2 to 4 35% 5 to 7	80% 2 to 4 20% 5 to 7	100% 2 to 4	......	......	......
S393	0.37	Grain size	1 hr., air cooled	.....	......	......	8	......	8	......	60% 2 to 3 40% 6, 7, 8	......	50% 2 to 3 50% 4 to 5	5% 2 80% 3 to 4 15% 5

[a] Grain size indicates austenite grain size.
[b] Protected against carburization by copper plating.
[c] Size 6 predominates.
[d] Grain size determinations by Battelle Memorial Institute

to be construed as any endorsement of shortening the period for regular creep tests.

GRAIN-COARSENING EXPERIMENTS

The K20 steel was originally prepared for use in cooperative creep tests to determine the degree of agreement between various laboratories using the A.S.T.M. Tentative Method E 22-35 T. This K20 steel was made and heat-treated with the sole idea of obtaining uniformity rather than creep resistance. Gillett[1] pointed out that this K20 steel (0.35 per cent) had a much lower creep resistance than several other annealed carbon steels and that the McQuaid-Ehn grain size of this K20 steel was considerably smaller than for the other annealed steels. Cross and Dahle's[5] report on steels F and LF had also pointed out the difference in grain size of those steels. It was suggested by P. E. McKinney that by a suitable grain-coarsening treatment the K20 steel of No. 8 grain size might be put in a better condition to resist creep.

In discussions of grain size in this report, unless specifically described otherwise, all grain size determinations are austenitic grain sizes resulting from the combination of times and temperatures used in the various heat treatments.

These austenitic grain sizes are not to be confused with the McQuaid-Ehn grain size, which is the grain size obtained as the result of carburizing for 8 hr. at a temperature of 1700 F. and which may have no bearing whatever on actual grain size.

The austenitic grain sizes listed in Table II are the actual austenite grain sizes established in the final heat treatment of the various materials prior to the creep tests, impact tests, and tension tests.

Specimens of K20, F and LF steels were carburized for 8 hr. in "Quick-lite A" at temperatures of 1600, 1700, 1800, and 1900 F. and cooled slowly in the pack in the furnace. Specimens for the Charpy impact test were heated at the same time, but on these, carburization was prevented by copper plating.

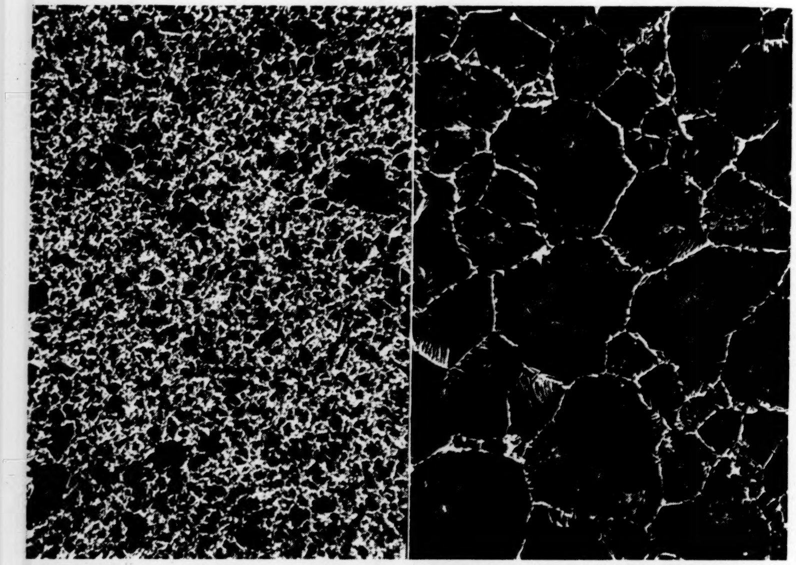
It may be seen that it was necessary to heat the K20 steel to 1900 F. before coarsening was obtained. The carbon steels F and LF show different coarsening characteristics. Steel LF shows beginning of coarsening at 1700 F., as part of the structure showed a grain size of 2, whereas steel F required 100 deg. higher temperature at 1800 F. to produce a similar effect. Note that after heating at 1900 F. the two steels show similar grain size.

For use in the creep test, bars of steels K20, F and LF were heated to 1900 F. for 2 hr. and air cooled. A 1-in. length of 1-in. round of each steel was heated at the same time, and when the bars for creep test were air cooled, these small pieces were cooled on end in $\frac{1}{4}$ in. of water. When sectioned about $\frac{1}{2}$ in. from the quenched end, they provide a convenient section for determining the austenite grain size.

It may be noted that steels F and LF show grain sizes comparable to those obtained by carburizing at 1900 F. for 8 hr. Steel K20 did not coarsen as much when heated to 1900 F. for 2 hr. as when carburized 8 hr. at 1900 F.; so the bars of K20 were reheated to 1900 F. for an additional 6 hr. and air cooled. The test on a small piece for grain size showed 0 to 3.

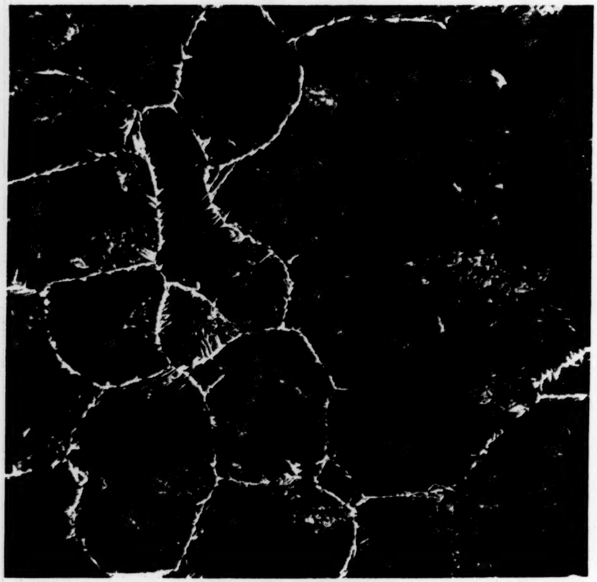
Steel 2807 with no aluminum added begins to coarsen at 1650 F., while steel 2809 (0.025 per cent aluminum) begins to coarsen at 1800 F. and steel 2810 (0.05 per cent aluminum) at 1850 F.

Steel 15 with no aluminum added was coarsened considerably with 1 hr. heating at 1650 F., while steel 18 taken from the same experimental heat but with 0.05 per cent aluminum added showed coars-



(*a*) Heated 1 hr. at 1550 F. Austenite grain size 8.

(*b*) Heated 2 hr. at 1900 F. Austenite grain size of 3 to 4.



(*c*) Heated 2 hr. at 1900 F. and additional 6 hr. at 1900 F. Austenite grain size of 0 to 3.

FIG. 1.—0.35 per cent Carbon Steel (K20) (× 100).

ening of the grain only at the rim after heating at 1800 F. and it was necessary to heat it to 1900 F. to obtain coarsening over the entire section in 1 hr. heating.

For steels 61 and 54, which had 0.025 per cent aluminum added, coarsening to a grain size of 2 to 4 was obtained by heating for $\frac{3}{4}$ hr. at 1650 F. and air cooling, while steels 56 and 52 with 0.10 and 0.105 per cent of aluminum added had to be heated to 1850 and 1800 F., respectively, to produce a grain size of 2 to 4.

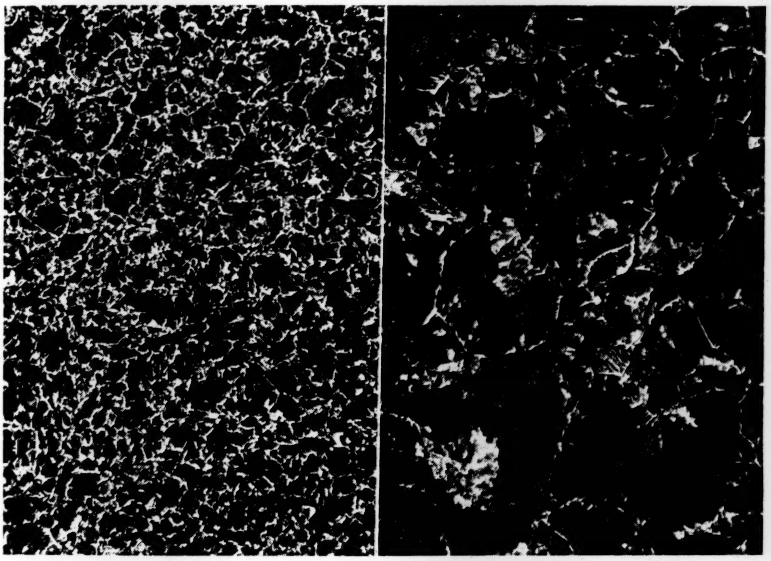

(a) Heated $\frac{3}{4}$ hr. at 1550 F. Austenite grain size of 6 to 8.
(b) Heated $\frac{3}{4}$ hr. at 1800 F. Austenite grain size of 2 to 4.

FIG. 2.—Steel 52 (0.48 per cent Carbon) (× 100).

The small blocks used for determination of the austenite grain size of steels 15, 18, 61, 54, 56, and 52 which had higher carbon contents than steel K20 were slow-cooled in the furnace from the heat treatment temperature. In higher carbon steels this is necessary to promote formation of the ferrite network which outlines the austenite grain.

To illustrate the structures developed for austenite grain size determinations at Battelle, fine and coarse-grained structures for two of the steels tested are shown in Figs. 1 and 2. The specimens were over etched intentionally and printed dark to accentuate the ferrite network in the austenite grain boundaries. All structures are shown at a magnification of 100. Figure 1 (*a*) shows the grain size (estimated 8) for the 0.35 per cent carbon steel (K20) developed by heating at 1550 F.

Figures 1 (*b*) and (*c*) show the grain sizes for the 0.35 per cent carbon steel (K20) developed by heating 2 hr. at 1900 F. (estimated 3 to 4) and by an additional 6 hr. heating at 1900 F. (estimated 0 to 3). Note the very large grain shown in Fig. 1 (*c*).

Figures 2 (*a*) and (*b*) show the grain sizes for steel 52 (0.46 per cent carbon) developed by heating $\frac{3}{4}$ hr. at 1550 F. (estimated 6 to 8) and by heating $\frac{3}{4}$ hr. at 1800 F. (estimated 2 to 4).

The carbon-vanadium steel No. S393 showed a fine grain of 8 when heated 1 hr. at temperatures up to 1700 F. Over 1700 F. grain coarsening began to take place but even heating at 2000 F. did not result in as coarse a grain as in the plain carbon steels.

This series of steels listed in Table II presented many interesting combinations for determining the effect of austenitic grain size on the creep resistance. The combinations used will be described along with the presentation of their creep test data.

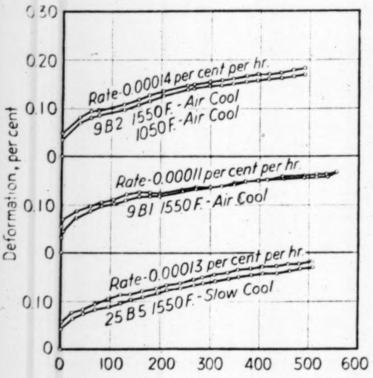


FIG. 3.—Time-Deformation Curves at 7500 lb. per sq. in. and 850 F. for 0.35 per cent Carbon Steel (K20). Grain size of 7 to 8.

CREEP TESTS AT 850 F.

For ease of comparison with the data obtained on the K20 steel as coarsened to be given later in this report, Fig. 3 shows the first 500 hr. of the time-deformation curve for specimen 25B5, tested in the original annealed condition at a load of 7500 lb. per sq. in. at 850 F. This is the long-time test bar that was tested for 20,342 hr. at 850 F. For the complete creep test curve, see Appendix II.[9] Since there are data indicating that for carbon steels better creep resistance is usually obtained in the normalized-and-drawn condition, it was deemed advisable to determine first the relative creep resistance of K20 as annealed, normalized, and normalized-and-drawn before determining the effect of coarsened grain size. Normalized at 1550 F., the same temperature as the annealing temperature, would not be expected to produce a change in grain size. The subsequent draw at 1050 F. for specimen 9B2 (K20) would likewise produce little if any change in grain size. Time-deformation curves in Fig. 3 for specimens 9B1 and 9B2 so treated show practically the same creep resistance as for the steel when annealed (25B5). Figure 4 shows the structure as tested for specimen 9B1, which was air cooled from 1550 F.

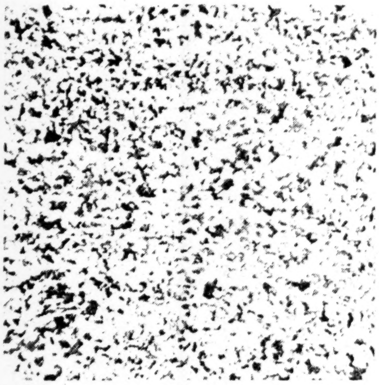


FIG. 4.—Structure of Creep Test Specimen 9B1 (0.35 per cent Carbon) (see Fig. 3) 1550 F., Air Cool. Austenite grain size of 7 to 8 (× 100).
Etched in 2 per cent Nital.

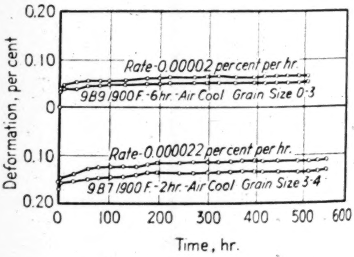


FIG. 5.—Time-Deformation Curves at 7500 lb. per sq. in. and at 850 F. for 0.35 per cent Carbon Steel (K20). Austenite grain size of 0 to 3, and 3 to 4.

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[9] See p. 121.

Detailed creep test data are shown in Table III for all of the steels tested.

Figure 5 shows the time-deformation curves for specimens 9B7 and 9B9 of steel K20 as grain-coarsened by heating at 1900 F. Note that the rates of deformation are less than for the steel with the fine grain by a ratio of 5 or 7 to 1. There was little, if any, difference in creep resistance between specimens 9B7 and 9B9 heated at 1900 F. for different times, both with coarse but different grain sizes.

TABLE III.—CREEP TEST DATA FOR STEELS TESTED. ALL TESTS AT 850 F.

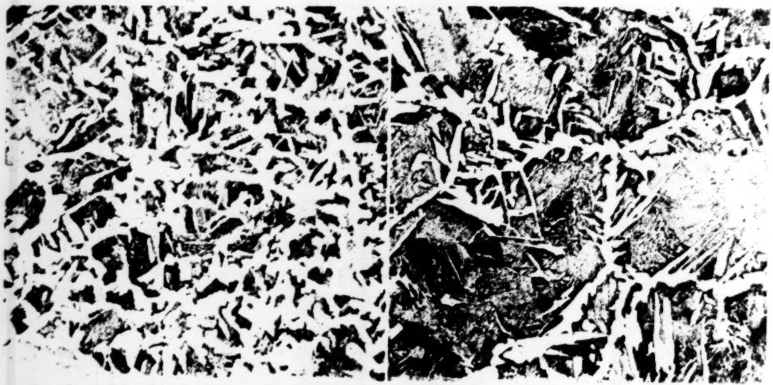
Steel Designation and Specimen Number	Carbon Content, per cent	Load, lb. per sq. in.	Average Initial Deformation, per cent	Rate of Deformation at 500 hr., per cent per hour	Average Total Deformation at 500 hr., per cent	Heat Treatment	Austenite Grain Size
K20-(25B5)	0.35	7 500	0.042	0.000130	0.175	1550 F., slow cool	8
K20-(9B1)	0.35	7 500	0.042	0.000110	0.160	1550 F., air cool	8
K20-(9B2)	0.35	7 500	0.040	0.000140	0.175	1550 F., air cool 1050 F., air cool	8
K20-(10A1)	0.35	10 000	0.053	0.000580	0.523	1550 F., slow cool	8
K20-(9B7)	0.35	7 500	0.038	0.000022	0.077	1900 F. 2 hr., air cool	3 to 4
K20-(9B9)	0.35	7 500	0.035	0.000020	0.059	1900 F. 2 hr., air cool 1900 F. 6 hr., air cool	0 to 3
K20-(9B11)	0.35	15 000	0.077	0.000045	0.158	1900 F. 6 hr., air cool	0 to 3
F-F7	0.37	12 000	0.060	0.000280	0.327	1550 F., air cooled	7 to 8
F-1	0.37	7 500	0.034	0.000025	0.064	1900 F. 2 hr., air cooled	−1 to 4
F-1	0.37	12 000[a]	0.084	0.000025[b]	0.107[b]	1900 F. 2 hr., air cooled	−1 to 4
LF-F2	0.27	12 000	0.058	0.000045	0.136	1550 F., air cooled	5 to 6
LF-1	0.27	7 500	0.035	0.000020	0.076	1900 F. 2 hr., air cooled	1 to 4
LF-1	0.27	12 000[a]	0.094	0.000020	0.126[b]	1900 F. 2 hr., air cooled	1 to 4
2807	0.28	15 000	0.081	0.000050	0.183	1650 F. 1 hr., air cool 1050 F. 2 hr., air cool	3 to 7
2809	0.29	15 000	0.084	0.000590	0.568	1650 F. 1 hr., air cool 1050 F. 2 hr., air cool	8
2810	0.28	15 000	0.091	0.005800[c]	1.350[c]	1650 F. 1 hr., air cool 1050 F. 2 hr., air cool	8
18-7	0.58	20 000	0.116	0.002100[d]	0.806[d]	1500 F. 1 hr., air cool	6 to 7
15-1	0.58	20 000	0.101	0.000280	0.470	1650 F. 1 hr., air cool	10% (1 to 2) 90% (3 to 4)
18-5	0.58	20 000	0.113	0.000390	0.465	1900 F. 1 hr., air cool	10% (1) 80% (2 to 4) 10% (5)
54-1	0.49	20 000	0.101	0.000235	0.425	1650 F. 45 min., air cool	2 to 4
61-1	0.52	20 000	0.117	0.000160	0.346	1650 F. 45 min., air cool	2 to 4
52-3	0.46	20 000	0.124	0.009100[e]	1.785[e]	1550 F. 45 min., air cool	6 to 8
52-1	0.46	20 000	0.110	0.000480	0.507	1800 F. 45 min., air cool	2 to 4
56-3	0.51	20 000	0.110	0.004150[e]	1.032[e]	1550 F. 45 min., air cool	6 to 8
56-1	0.51	20 000	0.091	0.000190	0.310	1850 F. 45 min., air cool	2 to 4
S393-1(f)	0.37	10 000	0.047	0.000060	0.120	1600 F. 1 hr., air cool	8
S393-2(f)	0.37	15 000	0.070	0.000135	0.236	1600 F. 1 hr., air cool	8
S393-3(f)	0.37	15 000	0.070	0.000056	0.164	2000 F. 1 hr., air cool	5% (2) 80% (3 to 4) 15% (5)

[a] After 500 hr. at 7500 lb. per sq. in., the load was raised to 12,000 lb. per sq. in. and the test continued for another 475 hr.
[b] At 475 hr.
[c] At 190 hr.
[d] At 200 hr.
[e] At 140 hr.
[f] Contained 0.18 per cent vanadium.

Figure 6 (*a*) shows the structure as tested for specimen 9B7 and Fig. 6 (*b*) shows the structure as tested for specimen 9B9. Note the difference in structure for specimen 9B9 due to the extra 6 hr. heating at 1900 F.

Since the tests on specimens 9B7 and 9B9 showed good creep resistance for the K20 steel in the coarsened condition, a test was run at double the load, that is, at 15,000 lb. per sq. in. at 850 F. The time-deformation curve for specimen 9B11 in Fig. 7 shows the results obtained. At twice the load, the rate of deformation was just about double that of specimens 9B7 and 9B9.

The creep rate of 0.000045 per cent per hour for specimen 9B11 (0 to 3 grain size) loaded to 15,000 lb. per sq. in. was about



(*a*) Specimen 9B7 (0.35 per cent Carbon) (see Fig. 5) 1900 F., 2 hr., air cool. Austenite grain size of 3 to 4.

(*b*) Specimen 9B9 (0.35 per cent Carbon) (see Fig. 5) 1900 F., 2 hr., air cool; 1900 F., 6 hr., air cool. Austenite grain size of 0 to 3.

FIG. 6.—Structure of Creep Test Specimens (× 100).
Etched in 2 per cent Nital.

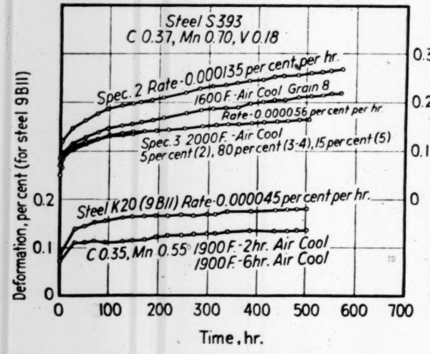


FIG. 7.—Time-Deformation Curves at 15,000 lb. per sq. in., and 850 F. for 0.35 per cent Carbon Steel (K20), and Carbon-Vanadium Steel S393 (0.37 per cent Carbon, 0.18 per cent Vanadium).

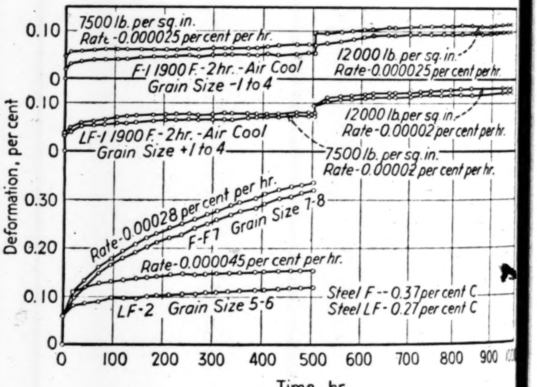
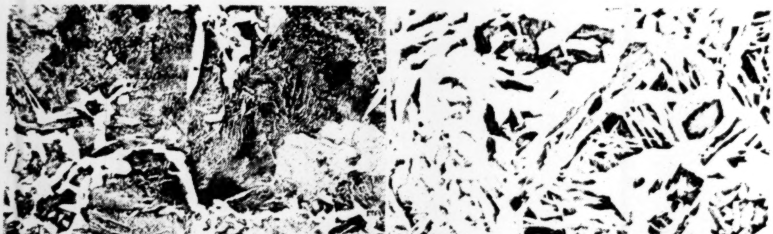


FIG. 8.—Time-Deformation Curves at 12,000 lb. per sq. in. and 850 F. for Steels F (0.37 per cent Carbon and LF (0.27 per cent Carbon).



(*a*) Specimen F-1 (0.37 per cent Carbon) (see Fig. 7) 1900 F., 2 hr., air cool. Austenite grain size of − 1 to 4.

(*b*) Specimen LF-1 (0.27 per cent Carbon) (see Fig. 7) 1900 F., 2 hr., air cool. Austenite grain size of 1 to 4.

FIG. 9.—Structure of Creep Test Specimens (× 100).
Etched in 2 per cent Nital.

one third the creep rate of 0.00014 per cent per hour for specimen 25B5 (7 to 8 grain size) loaded to only 7500 lb. per sq. in. at the same test temperature of 850 F. It may be seen that, as Mr. McKinney suggested, a tremendous improvement in creep resistance of this K20 (0.35 per cent carbon) steel has resulted from coarsening the grain. An approximate extrapolation indicates that the stress for 0.0001 per cent per hour for coarsened K20 steel would be in excess of 20,000 lb. per sq. in. at 850 F., a value which is certainly in the higher ranges for a steel of this carbon content, whereas in the annealed and fine-grained state this steel was considered to have poor creep resistance.

Figure 8 shows the time-deformation curves for the tests on steels F and LF. Note that as originally tested[5] as normalized from 1550 F., there was considerable difference in the creep resistance of the two steels. The lower carbon steel LF which had the smaller aluminum addition and had a coarser grain (5 to 6) than steel F (7 to 8) showed better creep resistance. Steel F (specimen F–F7 in Fig. 8) tested at 850 F. and 12,000 lb. per sq. in. showed a greater rate of deformation than steel K20 (specimen 25B5 in Fig. 3) tested at 7500 lb. per sq. in., while steel LF (specimen LF–F2 in Fig. 8) showed a lower rate of deformation than steel K20 even though tested at the higher load.

After heating at 1900 F. for 2 hr. and air cooling, steel F (specimen F–1) and steel LF (specimen LF–1) with similarly coarsened grain show similar creep resistance (see Fig. 8). Figures 9 (*a*) and (*b*) show the structure of creep test specimens F–1 and LF–1. These two steels as coarsened show about the same rate of deformation as steel K20 (specimen 9B7 in Fig. 5) similarly heat treated but with slightly different coarse grain. This is of particular interest, since both steels K20 and F in their original fine-grained condition would be considered poor from the standpoint of creep resistance as compared with published data on other steels of similar carbon content.

Since the rates of deformation for coarsened steels F and LF were so low, it was decided to increase the loads to 12,000 lb. per sq. in. to compare with the original tests[5] on these steels in which differences were shown (see Fig. 8). As in the tests at 7500 lb. per sq. in., at 12,000 lb. per sq. in. the two steels showed similar creep resistance. It may be seen therefore that the difference in creep resistance between steels F and LF in the fine-grained condition was eliminated by a coarsening heat treatment which produced a similar coarse grain size in each.

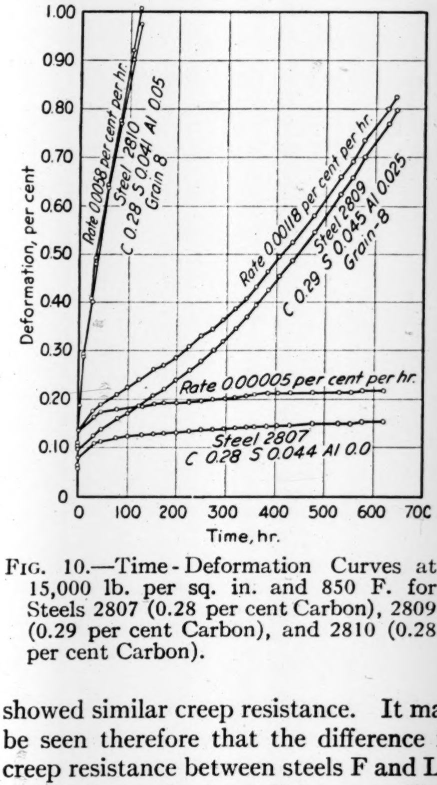
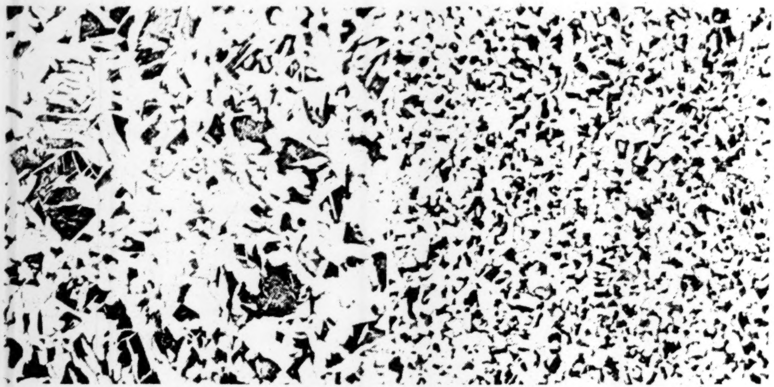


FIG. 10.—Time-Deformation Curves at 15,000 lb. per sq. in. and 850 F. for Steels 2807 (0.28 per cent Carbon), 2809 (0.29 per cent Carbon), and 2810 (0.28 per cent Carbon).

It was decided to heat treat at the same temperature steels 2807, 2809, and 2810 which had different aluminum additions. As expected and indicated in

Table III, normalizing from 1650 F. produced differences in austenite grain size between the steels.

Figure 10 shows the time-deformation curves for steels 2807, 2809, and 2810. Figures 11 (*a*) and (*b*) show the structure of creep test specimens 2807 and 2810. Steel 2807 with no aluminum added shows beyond question the best creep resistance. Steel 2809 with 0.025 per cent aluminum shows intermediate creep resistance and steel 2810 showed the poorest. Reference to Table II shows that steel 2807 with no aluminum began to coarsen when heated 1 hr. at 1650 F. As judged by visual examination, there was apparently no difference in grain size between steels 2809 and 2810, yet the time-deformation curves showed a definite difference in creep resistance. As shown in Table II, steel 2809 with the better creep resistance began to coarsen when heated 1 hr at 1800 F., while it was necessary to heat steel 2810 to 1850 F. before coarsening was observed. These data indicate that two steels with similar chemical composition and with apparently the same grain size as heat-treated and tested may show different creep properties. These steels upon further investigation were found to differ in their coarsening temperatures such that the steel with the lower coarsening temperatures showed the better creep properties. Analogous behavior, in tests on steels heated to different temperatures, in that the impact resistance at room temperature of some steels that are about to coarsen may fall before they have actually been observed to coarsen, has been noted in other work at Battelle. Apparently coming events cast their shadows before.


(*a*) Specimen 2807 (0.28 per cent Carbon) (see Fig. 10) 1650 F., 1 hr., air cool; 1050 F., 2 hr., air cool. Austenite grain size of 3 to 7.

(*b*) Specimen 2810 (0.28 per cent Carbon) (see Fig. 10) 1650 F., 1 hr., air cool; 1050 F., 2 hr., air cool. Austenite grain size 8.

FIG. 11.—Structure of Creep Test Specimens (× 100).
Etched in 2 per cent Nital.

Steels 15 and 18 from the same heat and differing only in that steel 15 had no aluminum added and steel 18 had 0.05 per cent aluminum permitted some interesting experiments.

Steel 15 (no aluminum) was tested as heated to and normalized from 1650 F. with an austenitic grain size observed to be about 10 per cent of 1 to 2 grain size and 90 per cent of 3 to 4 grain size.

Steel 18 (0.05 per cent aluminum) was tested as fine grained (6 to 7) obtained by heating to and normalizing from 1500 F. By experiment it was found that heating steel 18 to 1900 F. and then normalizing produced a grain size quite similar to that of steel 15 heated at 1650 F.

The time-deformation curves obtained at 20,000 lb. per sq. in. at 850 F. are shown in Fig. 12. Steel 18-5 as coarse grained shows a much better creep resistance than when in the fine-grained condition (18-7). The fine-grained steel showed a creep rate about 4 times as fast as the coarse-grained steel.

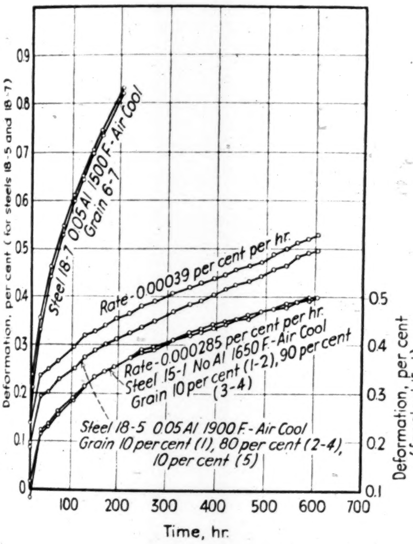


FIG. 12.—Time-Deformation Curves at 20,000 lb. per sq. in. and 850 F. for Steels 15 and 18 (0.58 per cent Carbon, 0.86 per cent Manganese, 0.14 per cent Silicon).

For steel 15-1, the ordinate in Fig. 12 has been moved down one block to prevent the curves for steel 18-5 and 15-1 from overlapping. The two time-deformation curves are very similar and the rates of deformation differ very little. It may be seen that by use of the proper coarsening treatment the grain size of the fine-grained steel 18 was made similar to that of the coarse grained steel 15 and under those conditions the creep resistance of the two steels was quite similar.

Another interesting comparison may be made using the data in Figs. 5, 7, and 12. It has been previously estimated that for the K20 steel as coarsened, a rate of 0.0001 per cent per hr. would result from a load in excess of 20,000 lb. per sq. in. at 850 F. Note in Fig. 12 that both steels 15-1 and 18-5 show rates in excess of 0.0001 per cent per hr. at this load and temperature. These data seem to check the findings of others, that increase in carbon content beyond a certain value around 0.35 to 0.4 per cent may result in decreased creep resistance rather than an improvement. Similarly, test data presented later in this report show steels 61, 54, 56, and 52, also with higher carbon contents than steel K20, to have a lower creep resistance than steel K20 when all are in the coarsened condition.

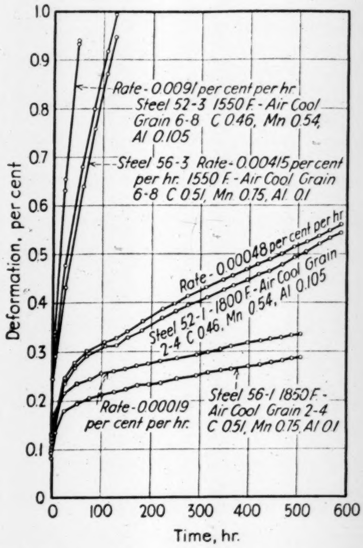


FIG. 13.—Time-Deformation Curves at 20,000 lb. per sq. in. and 850 F. for Steels 52 (0.46 per cent Carbon) and 56 (0.51 per cent Carbon).

Steels 61, 54, 56, and 52 were from different heats of approximately the same chemical composition. Steels 61 and 54 had 0.025 per cent aluminum added, while steels 56 and 52 had 0.10 and 0.105 per cent aluminum added. Tests were made on these four steels in a manner similar to the tests on steels 15 and 18.

The two fine-grained steels 56 and 52 were tested at 850 F. and 20,000 lb. per sq. in. as heated to 1550 F. and air cooled, which resulted in an austenite grain size of 6 to 8. These same steels were also tested with steel 56 heated to 1850 F. and air cooled and steel 52 heated to 1800 F. and air cooled, producing in both steels an austenitic grain size of 2 to 4.

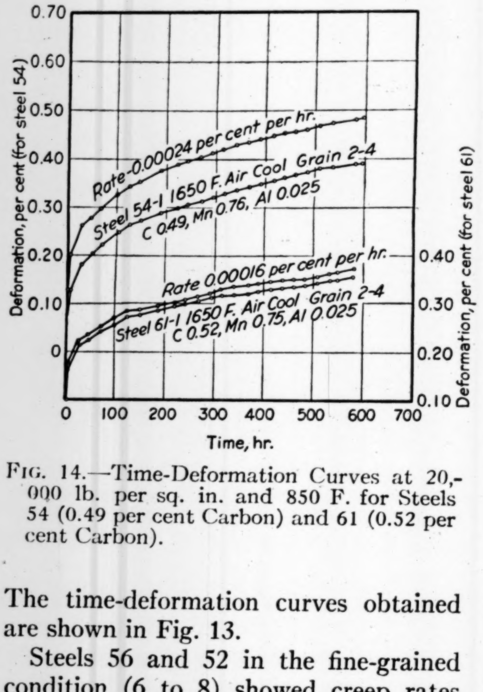


FIG. 14.—Time-Deformation Curves at 20,000 lb. per sq. in. and 850 F. for Steels 54 (0.49 per cent Carbon) and 61 (0.52 per cent Carbon).

The time-deformation curves obtained are shown in Fig. 13.

Steels 56 and 52 in the fine-grained condition (6 to 8) showed creep rates greater than the steels in the coarse-grained condition (2 to 4) by a ratio of about 20 to 1.

Steels 54 and 61 were heated at 1650 F. and air cooled to produce the same grain size (2 to 4) as was obtained in steels 56 and 52 by heating to 1850 and 1800 F. respectively. Their time-deformation curves at 850 F. and 20,000 lb. per sq. in. are shown in Fig. 14. The rate of deformation for steel 61 was a little less than for steel 56, while for steel 54 the rate was intermediate to those of steels 52 and 56. For the four tests at grain size of 2 to 4, the rates of creep at 500 hr. varied from 0.00016 to 0.00048 per cent per hr. Three of the steels, Nos. 54, 61, and 56, had the same manganese and silicon content, and their respective creep rates were 0.000245, 0.00016, and 0.00019 per cent per hr. respectively, while steel 52 with 0.54 per cent manganese showed the higher rate of 0.00048 per cent per hr. Jenkins and co-workers [3] noted that none of their steels containing 0.60 per cent manganese showed poor creep resistance; the poor ones had below 0.50 per cent. This difference in manganese content is merely mentioned as falling in line with their observations. The difference of 0.2 per cent manganese may or may not be significant.

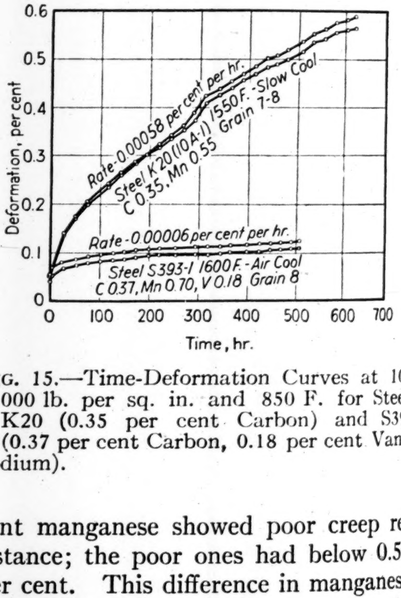


FIG. 15.—Time-Deformation Curves at 10,000 lb. per sq. in. and 850 F. for Steels K20 (0.35 per cent Carbon) and S393 (0.37 per cent Carbon, 0.18 per cent Vanadium).

For steels 52 and 56 the difference between the creep resistance of the fine-grained and coarse-grained conditions was greater than for steel 18, although the creep resistance of steels 52, 56, and 18 as coarse grained was not greatly different. Conversely the creep resistance of steel 18 as fine grained was superior to that of steels 56 and 52 with the same fine grain of about 6 to 8.

For these steels 54, 61, 52 and, 56, as was the case with steels 15 and 18, their creep resistance in the coarse-grained condition did not seem as good as for the lower carbon K20 steel in that at 20,000 lb. per sq. in. rates in excess of 0.0001 per cent per hr. were produced by a load of 20,000 lb. per sq. in. at 850 F.

Creep tests were made on the carbon-vanadium steel to compare its behavior with that of steels made fine grained by aluminum. Figure 15 shows the time-deformation curves for fine-grained K20 0.35 per cent carbon steel and the carbon-vanadium (0.37 per cent carbon) steel. The carbon-vanadium steel shows much better creep resistance with both steels in the fine-grained condition (7 to 8) and tested at 10,000 lb. per sq. in. at 850 F. The carbon-vanadium steel showed about one-tenth the rate of the K20 0.35 per cent carbon steel.

Since the rate for the fine-grained carbon-vanadium steel at 10,000 lb. per sq. in. was quite low, it was decided to compare this steel in the fine- and coarse-grained conditions at the higher load of 15,000 lb. per sq. in. at 850 F. and to compare the coarse-grained carbon-vanadium and K20 steels at the same load. Figure 7 shows the time-deformation curves obtained. Coarsening the grain of the carbon-vanadium steel resulted in a small improvement in creep resistance; the ratio of the creep rate as fine grained to that as coarse grained was about $2\frac{1}{2}$ to 1. Thus, for this carbon-vanadium steel which already had fair resistance as fine grained, coarsening caused only a little improvement in creep resistance.

It is of exceeding interest to compare in Fig. 7 the time-deformation curves for specimen 3 of the carbon-vanadium steel and for specimen 9B11 (K20 steel). The K20 steel heated to 1900 F. as indicated had a coarser grain (0 to 3) than did the carbon-vanadium steel heated to 2000 F. (5 per cent of 2, 80 per cent of 3 to 4, 15 per cent of 5). Their creep rates were nearly alike, with the lower rate shown by the K20 steel which possessed the coarser grain. Apparently the superiority in creep resistance possessed by the carbon-vanadium steel when compared with the K20 plain carbon steel in the fine-grained condition practically disappeared when the two steels were compared in the coarse-grained condition at 850 F.

CREEP TESTS AT 750 AND 950 F.

For many years the relative creep resistance of fine-grained steels as compared with coarse-grained steels has been investigated and discussed. Some investigators have advanced the theory that, as a general rule, fine-grained steels show the better creep resistance at lower temperatures, while the coarse-grained steels are better at higher temperatures. The dividing line between the two temperature ranges has sometimes been considered to be the equicohesive temperature, and defined by some as the lowest temperature of recrystallization. However, exceptions to this theory have been pointed out in which at high temperatures no superiority was shown by coarse-grained steels.

Since such large differences in creep resistance due to variations in grain size have been shown in this report to occur at 850 F., it seemed desirable to determine whether similar effects also would be observed at temperatures both above and below 850 F. Accordingly creep tests have been made at 750 and 950 F. on some of the steels tested at 850 F. The test material used was heat treated so as to produce austenite grain sizes exactly comparable to those existing in the specimens tested at 850 F. Each of the steels was tested as fine grained and as coarse grained.

The time-deformation curves for the steels tested at 750 F. and 28,000 lb. per sq. in. are shown in Figs. 16, 17, and 18. Detailed creep test data are shown in Table IV for the tests at 750 and 950 F.

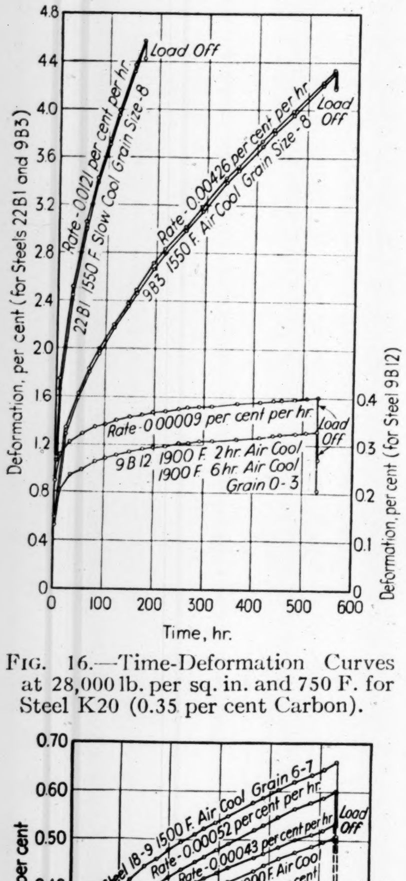


FIG. 16.—Time-Deformation Curves at 28,000 lb. per sq. in. and 750 F. for Steel K20 (0.35 per cent Carbon).

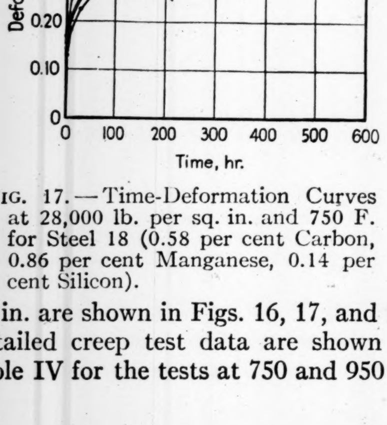


FIG. 17.—Time-Deformation Curves at 28,000 lb. per sq. in. and 750 F. for Steel 18 (0.58 per cent Carbon, 0.86 per cent Manganese, 0.14 per cent Silicon).

Figure 16 shows the curves for 0.35 per cent carbon steel (K20) tested at 750 F. As in the tests at 850 F., specimen 9B12 with the coarsened grain showed a lower rate of deformation than did specimens 22B1 and 9B3 with fine grain. The difference in creep rate shown by the K20 steel with fine and coarse grain was greater at 750 F. than at 850 F.

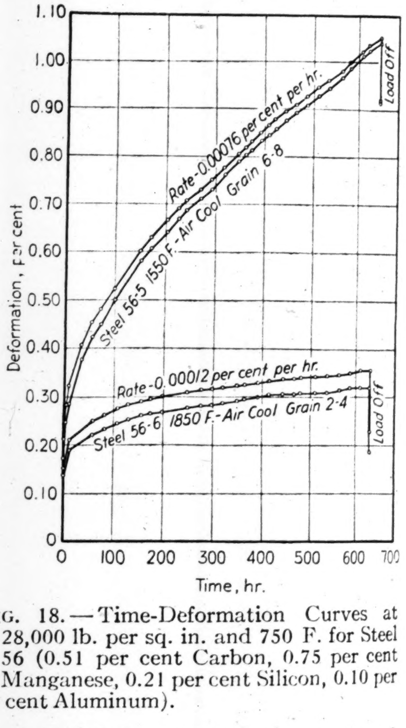


FIG. 18.—Time-Deformation Curves at 28,000 lb. per sq. in. and 750 F. for Steel 56 (0.51 per cent Carbon, 0.75 per cent Manganese, 0.21 per cent Silicon, 0.10 per cent Aluminum).

At 850 F. and 7500 lb. per sq. in., the fine-grained K20 steel showed a creep rate about six times that for the coarse-grained K20 steel, while at 750 F. and 28,000 lb. per sq. in. the ratio was about 120 to 1 for the slow-cooled K20 steel and about 43 to 1 for the normalized K20 steel.

For steels 18 and 56 at 750 F. (see Figs. 17 and 18), while a slight superiority in creep resistance was shown by the coarse-grained specimens, the differences between the creep rates for fine-grained and coarse-grained specimens

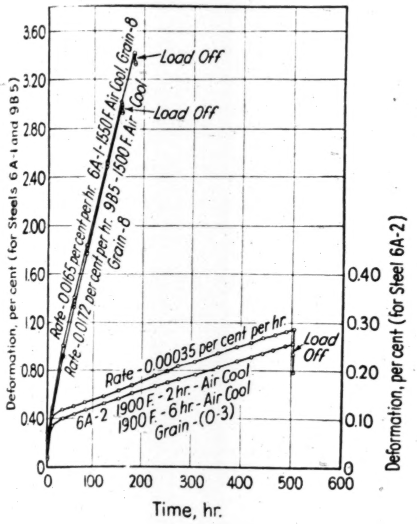


FIG. 19.—Time-Deformation Curves at 11,000 lb. per sq. in. and 950 F. for Steel K20 (0.35 per cent Carbon).

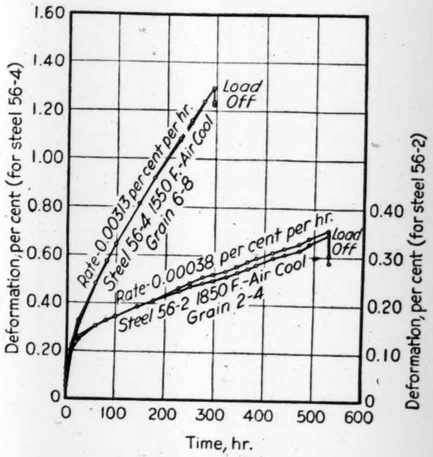


FIG. 21.—Time-Deformation Curves at 11,000 lb. per sq. in. and 950 F. for Steel 56 (0.51 per cent Carbon, 0.75 per cent Manganese, 0.21 per cent Silicon, 0.10 per cent Aluminum).

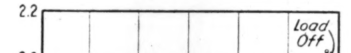


FIG. 20.—Time-Deformation Curves at 11,000 lb. per sq. in. and 950 F. for Steel 18 (0.58 per cent Carbon, 0.86 per cent Manganese, 0.14 per cent Silicon).

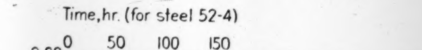


FIG. 22.—Time-Deformation Curves at 11,000 lb. per sq. in. and 950 F. for Steel 52 (0.46 per cent Carbon, 0.75 per cent Manganese, 0.23 per cent Silicon, 0.10 per cent Aluminum).

were less than obtained at 850 F. In fact for steel 18 at 750 F. the creep rates were 0.00052 and 0.00043 per cent per hr. for the fine-grained and coarse-grained steels, respectively. For steel 56 the ratio was 6 to 1 as compared with 22 to 1 at 850 F.

As in the tests at 850 F. on the coarsened steels, the 0.35 per cent carbon steel showed the best creep resistance, and steel 56 was better than steel 18.

In addition to steels 18 and 56, steel 52 was also tested at 950 F. For all three steels the rates of deformation were lower for coarse-grained specimens as compared with fine-grained specimens. For steels 18 and 56, the ratios of the creep rates between the coarse-grained and fine-grained specimens were lower at 950 F. than at 850 F., while for steel 52 the ratios at the two temperatures were about equal. Coarsened steel 56 showed

TABLE IV.—CREEP TEST DATA FOR STEELS TESTED AT 750 AND 950 F.

Steel Designation and Specimen Number	Carbon Content, per cent	Temperature of Test, deg. Fahr.	Load, lb. per sq. in.	Average Initial Deformation, per cent	Rate of Deformation at 500 hr., per cent per hour	Average Total Deformation at 500 hr., per cent	Heat Treatment	Austenite Grain Size
22B1 (K20).......	0.35	750	28 000	1.076	0.0121[a]	4.56[a]	1550 F., slow cool	8
9B3 (K20).......	0.35	750	28 000	0.570	0.00426	4.08	1550 F., air cool	8
9B12 (K20).......	0.35	750	28 000	0.185	0.00009	0.360	1900 F. 2 hr., air cool 1900 F. 6 hr., air cool	0 to 3
18-9............	0.58	750	28 000	0.155	0.00052	0.614	1500 F. 1 hr., air cool	6 to 7
18-10...........	0.58	750	28 000	0.139	0.00043	0.504	1900 F. 1 hr., air cool	10% of 1 80% of 2 to 4 10% of 5
56-5............	0.51	750	28 000	0.190	0.00076	0.932	1550 F. 45 min., air cool	6 to 8
56-6............	0.51	750	28 000	0.144	0.00012	0.323	1850 F. 45 min., air cool	2 to 4
6A1 (K20)........	0.35	950	11 000	0.071	0.0165[b]	3.415[b]	1550 F., slow cool	8
9B5 (K20)........	0.35	950	11 000	0.078	0.0172[c]	3.02[c]	1550 F., air cool	8
6A2 (K20)........	0.35	950	11 000	0.062	0.00035	0.272	1900 F. 2 hr., air cool 1900 F. 6 hr., air cool	0 to 3
18-8............	0.58	950	11 000	0.070	0.00288	1.80	1500 F. 1 hr., air cool	6 to 7
18-6............	0.58	950	11 000	0.072	0.00093	0.706	1900 F. 1 hr., air cool	10% of 1, 80% of 2 to 4 10% of 5
52-4............	0.46	950	11 000	0.062	0.012[d]	1.95[d]	1550 F. 45 min., air cool	6 to 8
52-2............	0.46	950	11 000	0.067	0.00066	0.493	1800 F. 45 min., air cool	2 to 4
56-4............	0.51	950	11 000	0.057	0.00313[e]	1.295[e]	1550 F. 45 min., air cool	6 to 8
56-2............	0.51	950	11 000	0.063	0.00038	0.335	1850 F. 45 min., air cool	2 to 4

[a] At 168 hr.
[b] At 180 hr.
[c] At 154 hr.
[d] At 142 hr.
[e] At 294 hr.

The time-deformation curves for the steels tested at 950 F. and 11,000 lb. per sq. in. are shown in Figs. 19, 20, 21, and 22. Their detailed creep test data are shown in Table IV.

Figure 19 shows the curves for the 0.35 per cent carbon steel tested at 950 F. and as in the tests at 750 and 850 F., the coarse-grained specimen 6A2 showed a lower rate of deformation than the fine-grained specimens 6A1 (slow cooled from 1550 F.) and 9B5 (air cooled from 1550 F.) with the ratio about 50 to 1.

TABLE V.—RATIO OF RATES OF DEFORMATION OF FINE-GRAINED STEELS AND COARSE-GRAINED STEELS.

Steel	Creep Test Temperature 750 F.	Creep Test Temperature 850 F.	Creep Test Temperature 950 F.
0.35 per cent Carbon Steel K20			
	At 28,000 lb. per sq. in.	At 7500 lb. per sq. in.	At 11,000 lb. per sq. in.
Slow cooled *versus* coarse grained....	120 to 1	6 to 1	50 to 1
Air cooled *versus* coarse grained....	43 to 1	6 to 1	50 to 1
		At 20,000 lb. per sq. in.	
18..................	1 to 1	5 to 1	3.1 to 1
52..................	....	19 to 1	18 to 1
56..................	6 to 1	22 to 1	8 to 1

a rate of deformation at 950 F. similar to that of coarsened K20 steel. Steels 18 and 52 showed a higher rate of deformation at 950 F. than steels K20 and 56.

Table V shows the ratio of the rates of deformation of the steels as fine grained to the steels as coarse grained, with the rate as coarse grained taken as unity.

The four steels were tested at the same loads of 28,000 lb. per sq. in. at 750 F., and 11,000 lb. per sq. in. at 950 F. At 850 F., steels 18, 52, and 56 were tested at 20,000 lb. per sq. in. but steel K20 was tested at 7500 lb. per sq. in. This accounts for the very low ratio at 850 F. for steel K20. At higher loads the ratio would have been much greater. Figure 23 shows the spread between the creep rates for the fine-grained and coarse-grained steels at the various temperatures and loads. The effect of grain size varies widely with load and temperature but in all tests made, the results are invariably in favor of the coarser grain.

For plain carbon steels it has been thought that the so-called equicohesive temperature was to be found in the range 750 to 950 F. Since all of the tests at 850 F. showed coarse-grained steels to have better creep resistance than the same steels as fine grained, this so-called equicohesive temperature is indicated to be less than 850 F. for the steels tested. For steels K20 and 56 it is indicated to be less than 750 F. Steel 18 at 750 F. did show almost the same rate with 0.00052 and 0.00043 per cent per hr. for the fine grained and coarse-grained specimens respectively.

These data strongly indicate that for steels of the composition tested over the usual service range of 750 to 950 F. for carbon steels, better creep resistance consistently will be obtained with steels of coarse grain structure as measured by austenite grain size.

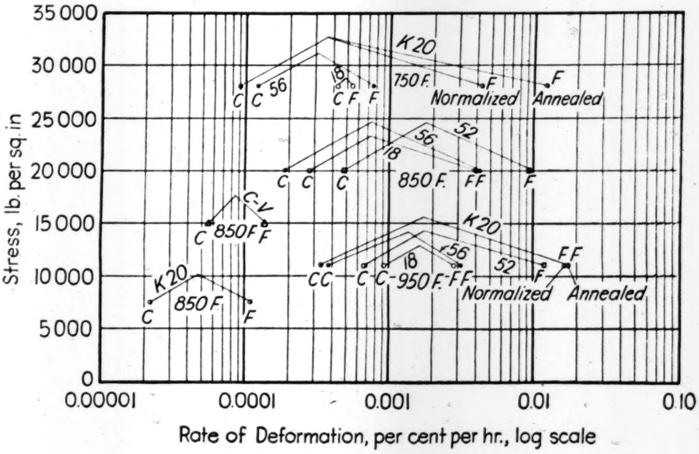


FIG. 23.—Effect of Grain Size on Creep Rate of Various Steels at Different Loads and Temperatures.

EFFECT OF AUSTENITE GRAIN SIZE ON THE RELAXATION CHARACTERISTICS OF 0.35 PER CENT CARBON STEEL (K20)

To obtain a further check on the better creep resistance of coarse-grained K20 steel as compared with the steel as fine grained, Mr. Mochel of the South Philadelphia works of the Westinghouse Electric and Manufacturing Co. was requested to make a few relaxation tests on specimens heat treated similarly to those used in the creep tests. The apparatus and test method employed were described in the *Transactions* of the American Society for Mechanical Engineers, July, 1937, pp. 453–455. A slight modification was necessary in the threaded or end sections so as to use the 1-in. diameter bars. A test specimen of 0.505-in. diameter and 10-in. gage length was used. The results of the relaxation test are shown in Table VI.

The coarse-grained steel showed a final stress about 30 per cent greater than did the fine-grained steel, thus agreeing with the creep results in showing superiority of the coarser grain.

TABLE VI.—RELAXATION TESTS ON 0.35 PER CENT CARBON STEEL (K20).

Temperature of Test, 850 F.
Duration of Test, 1000 hr.

Specimen	Austenite Grain Size	Brinell Hardness Before Test	Brinell Hardness After Test	Initial Stress, lb. per sq. in.	Final Stress, lb. per sq. in.
No. 40B1....	8[a]	131	137	7500	3250
No. 40B2....	8[a]	131	137	7500	3100
No. 40B3....	3 to 4[b]	156	163	7500	4100
No. 40B4....	3 to 4[b]	156	163	7500	4100

[a] Slow cooled from 1550 F.
[b] Heated 6 hr. at 1900 F., air cooled.

ROOM TEMPERATURE PHYSICAL PROPERTIES OF THE STEELS AS FINE GRAINED AND COARSE GRAINED

It is pertinent to inquire what are the effects of these various coarsening heat treatments on the room temperature physical properties of the various steels. Steels for use at elevated temperatures to resist creep should also possess suitable tensile strengths, ductilities, and toughness at room temperature. Table VII shows the available room temperature physical properties of the various steels tested.

Coarsening the grain of the carbon steels, as has been shown above, increases their creep resistance. Coarsening brings all the steels pretty much into line as to creep resistance, in spite of great variations that exist when grain size is ignored. This coarsening generally slightly raises room temperature tensile and yield strengths and slightly decreases ductility. In steels of low coarsening temperature, coarsening materially reduces impact resistance, but in those of high coarsening temperature the impact resistance is only moderately reduced; the final value is less in the higher carbon steels. Thus it is indicated that for optimum combination of creep resistance and room temperature toughness, a coarsened carbon steel, but one of high coarsening temperature, would be preferred to one coarsened to the same degree but at a lower temperature.

Neither the impact nor the creep resistance is controlled solely by grain size. Steels of similar composition brought to the same grain size may vary from each other within a fairly narrow range. The position in this range seems to be affected by the coarsening temperature as well as the actual grain size. Before one attempts to compare the effects of alloying elements on either creep or impact, not only the actual grain size but also the coarsening characteristics of the alloyed steels, that is, the treatment of the melt for grain size control, should be comparable.

For a fine-grained steel, the creep resistance of the carbon-vanadium steel was outstanding. Coarsening this only slightly improved creep resistance, bringing it up to the level of the other coarse-grained steels and ruined its impact resistance. Perhaps some treatment at an intermediate temperature would preserve a good combination of properties. The impact resistance of the high-carbon non-aluminum treated steels Nos. 54 and 61 was also ruined by coarsening. Among the steels and treatments herein reported on, one would choose the fine-grained carbon-vanadium steel if impact were considered more important than creep

TABLE VII.—ROOM TEMPERATURE PHYSICAL PROPERTIES OF THE FINE-GRAINED AND COARSE-GRAINED STEELS.

Steel Designation and Specimen Number	Carbon Content, per cent	Heat Treatment	Austenite Grain Size	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Charpy Impact Resistance, ft-lb.[a]	Izod Impact Resistance, ft.-lb.[b]
K20	0.35	1550 F., slow cooled	8	44 110	69 500	38.5	65.8	32, 31, 33	49, 49, 46
K20	0.35	1900 F. 2 hr., air cooled	3 to 4	46 150	83 420	29.7	54.6	27, 24, 25	33, 34, 35
K20	0.35	1900 F. 2 hr., air cooled and 1900 F. 6 hr., air cooled	0 to 3	40 350	85 900	28.0	53.3	24	26
F	0.37	1550 F., air cooled	7 to 8	45 950	80 000	28.0	39.0	22, 19, 22	34, 33, 33
F	0.37	1900 F. 2 hr., air cooled	−1 to 4	47 120	96 800	23.5	47.9	19, 17, 19	
LF	0.27	1550 F., air cooled	5 to 6	37 050	67 550	32.0	52.2	26, 23, 26	39, 39, 46
LF	0.27	1900 F. 2 hr., air cooled	1 to 4	37 750	70 850	32.0	54.1	28, 34, 32	
2807	0.28	1650 F. 1 hr., air cooled and 1050 F. 2 hr., air cooled	3 to 7	43 900	76 100	32.0	60.6	33, 30	
2809	0.29	1650 F. 1 hr., air cooled and 1050 F. 2 hr., air cooled	8	50 200	77 100	32.0	60.8	35, 33	
2810	0.28	1650 F. 1 hr., air cooled and 1050 F. 2 hr., air cooled	8	52 500	76 550	33.0	63.0	37, 38	
15	0.58	1650 F. 1 hr., air cooled	10% of 1 to 2, 90% of 3 to 4	63 250[c]	121 250	14.0	30.7	10.5, 9.5	8, 9, 8
18	0.58	1500 F. 1 hr., air cooled	6 to 7	58 850[c]	115 250	19.2	43.4	15, 16	11, 14, 14
18	0.58	1900 F. 1 hr., air cooled	10% of 1, 80% of 2 to 4, 10% of 5	59 950	119 100	16.7	36.9	12, 13	14, 11, 8
54	0.49	1650 F. $\frac{3}{4}$ hr., air cooled	2 to 4	49 250	99 750	22.7	43.4	4.4, 5.8	4.5, 4.5, 3.5, 4.0
61	0.52	1650 F. $\frac{3}{4}$ hr., air cooled	2 to 4	53 500	107 500	20.7	40.4	3.8, 3.8	5.0, 4.0, 4.0, 3.0
52	0.46	1550 F. $\frac{3}{4}$ hr., air cooled	6 to 8	55 750	91 500	27.3	50.8	19, 20	25, 25, 28, 29
52	0.46	1800 F. $\frac{3}{4}$ hr., air cooled	2 to 4	51 250	92 000	25.3	46.9	14, 15	17, 17, 20, 19
56	0.51	1550 F. $\frac{3}{4}$ hr., air cooled	6 to 8	59 500	101 750	25.0	49.1	16, 15	24, 22, 24, 23
56	0.51	1800 F. $\frac{3}{4}$ hr., air cooled	2 to 4	57 500	106 000	21.5	42.0	13, 12	15, 16, 17, 15
S393	0.37	1600 F. 1 hr., air cooled	8	76 400	96 400	22.0	45.2	....	52, 40
S393	0.37	2000 F. 1 hr., air cooled	5% of 2, 80% of 3 to 4, 15% of 5	93 400	132 100	12.5	23.7	....	3.5, 8.5

[a] Keyhole notch.

[b] V notch.

[c] Criterion, 0.2 per cent.

resistance, a coarsened carbon steel of high coarsening temperature if best creep and fair impact were sought.

SUMMARY

Creep tests at 850 F. on the 0.35 per cent carbon steel (K20) have shown that the stress required to produce a creep rate of 0.0001 per cent per hour was more than doubled by use of a high-temperature normalizing treatment which produced a marked coarsening of the austenitic grain size.

Of two plain carbon steels (F, 0.37 per cent carbon, and LF, 0.27 per cent carbon), both heat treated at the same temperature of 1550 F., steel LF with the coarser austenite grain size was superior in creep resistance. Use of a higher heat treatment temperature for the two steels to produce a similar coarse grain size resulted in both showing a better and similar creep resistance.

Three carbon steels of similar chemical composition (0.28 per cent carbon) but with different aluminum additions were heat treated at the same temperature of 1650 F. The steel with no aluminum and the coarsest grain size showed the best creep resistance. The other two steels were finer and their creep resistance was poorer. Although both showed the same austenite grain size, the one with the lower aluminum addition showed better creep resistance and further tests showed it possessed the lower coarsening temperature.

Six other plain carbon steels (0.46 to 0.58 per cent carbon) were tested at 850 F. Creep rates for three of these steels as fine grained were from 10 to 20 times the creep rates for the same three steels as coarse-grained. The other three steels which had low coarsening temperatures due to lower aluminum additions showed comparable high creep resistance to the first three steels when heat treated to produce the same coarse grain.

A carbon-vanadium steel (0.37 per cent carbon, 0.18 per cent vanadium), which showed much better creep resistance than steel K20 (0.35 per cent carbon) as fine grained, was improved only a little by coarsening of the grain, and with both coarse-grained, it showed similar creep resistance to the plain carbon steel.

Three of the steels were tested at 750 F. and four of the steels were tested at 950 F. Except for one steel at 750 F., marked superiority in creep resistance was shown for coarse-grained steels. For that one steel at 750 F. the rates of deformation were nearly alike with a slight superiority shown by the coarse-grained material.

Data on the room temperature physical properties of the various steels in the fine-grained and coarse-grained conditions show that for steel K20 (0.35 per cent carbon), grain coarsening by heating to a high temperature and normalizing produced considerably higher tensile properties with only small changes in ductility in tension or impact as compared with the annealed steel.

Steel F (0.37 per cent carbon) showed higher tensile strength when coarsened, while steel LF (0.27 per cent carbon) showed practically no change in tensile properties or impact.

Steel 18 (0.58 per cent carbon) showed a slight decrease in tension ductility and impact resistance on coarsening. Steel 15 (0.58 per cent carbon) coarsened at a lower temperature showed slightly better strength but poorer tension ductility and impact resistance.

Steels 2807, 2809, and 2810 (0.28 per cent carbon with varying aluminum) differed only in yield point while showing large differences (115 to 1) in creep.

Steels 52 and 56 (0.46 and 0.51 per cent carbon, 0.105 and 0.10 per cent aluminum) showed a slight decrease in tension ductility and impact on coarsening, but steels 54 and 61 (0.49 and 0.52 per cent carbon, 0.025 per cent aluminum) when coarsened to the same grain size at a considerably lower heat treatment temperature show equal tensile properties and ductility but poor impact resistance. These data indicate combined good creep resistance and impact resistance can be obtained by coarsening an aluminum-treated fine-grained steel rather than by using a steel of low coarsening temperature with the same grain size.

The carbon-vanadium steel (0.37 per cent carbon, 0.18 per cent vanadium), which possessed the best creep resistance as finegrained, also showed the best tensile properties and ductility along with good impact resistance. Coarsening of this carbon-vanadium steel markedly increased the tensile properties but reduced the tensile ductility and produced poor impact resistance.

The test data contained herein have suggested the desirability of determining the grain sizes of semi-killed and rimming steels and the relation of this grain size to the creep resistance as compared with killed steels of similar chemical composition. Such a series of tests would be very interesting when it is considered that data in the literature show killed steel to be superior in creep resistance to rimming steels, yet on the basis of aluminum additions to each, the rimming steel might be expected to have the coarser grain.

It is not believed that grain size is the only variable affecting creep resistance; indeed it is expected that once the huge variations that are definitely ascribable to it are clarified, it will then be possible to untangle and study the effect of other factors, such as those of small variations in composition and of other manufacturing variables beside those affecting grain size. Such effects have hitherto often been obliterated by variations in grain size.

DISCUSSION

MR. ARCHIBALD HURTGEN.[1]—The behavior of medium-carbon steels under creep loading, in the light of present information, is indeed interesting. The improved creep properties of wrought carbon steels resulting from prolonged exposure to very high temperatures is a matter which is vitally important and indispensable to the consideration of facts in the selection of a proper heat treatment for best creep behavior.

Until a relatively short time ago, A.S.T.M. Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 36)[2] did not require normalizing or annealing treatments to be given the forgings subsequent to the finish forging operation. This report by Cross and Lowther implies that, in reality, the high-temperature properties of the medium-carbon steels (the material which is usually supplied under Specifications A 105) will actually be impoverished through either the normalizing or annealing treatment intended and customarily employed for obtaining refinement of the grain. In this connection the writer's experience indicates that the customary finish-forging temperature of these materials (referring to those supplied under Specifications A 105) is in the vicinity of 1750 F., minimum.

It is the writer's impression that the coarsening treatments employed and the creep data obtained on such coarsened material as reported by Cross and Lowther should not be construed as forming a basis for the general predication of creep behavior of these medium-carbon steels on grain size alone.

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[1] Chief Metallurgist, Henry Vogt Machine Co., Louisville, Ky.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 312.

APPENDIX VI

REPORT COVERING INFORMATION ON STEELS FOR TUBULAR CREEP TESTS AND OTHER TEST WORK OF THE JOINT COMMITTEE

(PROJECT No. 19)

PREPARED BY H. J. KERR, J. B. ROMER, AND H. D. NEWELL

Material Ordered:

Carbon-Molybdenum Steel

4 Billets, 5 in. in diameter by 134½ in. long (748 lb. cut to weight).
20 ft., 5-in. diameter round bar.
10 ft., 1½-in. diameter round bar.

4 to 6 per cent Chromium-Molybdenum Steel

3 Billets, 5 in. in diameter by 134½ in. long (748 lb. cut to weight).
3 Billets, 5 in. in diameter by 102 in. long.
10 ft., 1½-in. diameter round bar.

The four cut length carbon-molybdenum billets and the three 134½-in. cut lengths 4 to 6 per cent chromium-molybdenum billets were rolled into 4½ in. outside diameter tubes by ¾ in. wall random lengths providing,

80 ft. of carbon-molybdenum steel tubes.
60 ft. of 4 to 6 per cent chromium-molybdenum steel tubes.

Analysis of the material:

	Carbon-Molybdenum Steel Heat No. 37239		4 to 6 per cent Chromium-Molybdenum Steel Heat No. 57390	
	Ladle Analysis	Check Analysis	Ladle Analysis	Check Analysis
Carbon, per cent	0.15	0.146	0.09	0.092
Manganese, per cent......	0.53	0.54	0.39	0.43
Sulfur, per cent.	0.016	0.018	0.016	....
Phosphorus, per cent......	0.016	0.015	0.010	....
Silicon, per cent	0.21	0.21	0.28	0.21
Chromium, per cent......	....	....	4.85	4.79
Molybdenum, per cent......	0.56	0.53	0.53	0.51

The 1½-in. round bars were not from the same heat as the tubes and 5-in. diameter billets, therefore they were not used for test purposes. These two bars are in the Barberton Laboratory.

Manufacturer's Data:

Information pertinent to the manufacture of the steel described herein was supplied by the Crucible Steel Co. of America. The data given follow:

Carbon-Molybdenum Steel

1. Type melting furnace—Open hearth
2. Capacity—60 tons
3. Lining type—Basic
4. Ingot size—1½ in. round bars: 21 in. square, top, 19 in. square, bottom, weight, 7000 lb.
   5-in. diameter billets: 18 in. square, top, 16 in. square at bottom, weight, 5000 lb.
5. Location or ingot cut—Bars for creep tests taken from middle cut.

4 to 6 per cent Chromium-Molybdenum Steel

1. Type melting furnace—Electric arc
2. Capacity—10 tons
3. Lining type—Basic
4. Ingot size—21 in. by 21 in. top, 19 in. by 19 in. bottom, weight 7000 lb.
5. Location or ingot cut—Bars for creep tests taken from middle cut.

The tubes were pierced by The Babcock & Wilcox Co. at Beaver Falls.

Heat Treatment of Tubes and Bars:

Bars and tubes of each grade were annealed together in a car-type gas fired annealing furnace. The annealing treatment for the materials was as follows:

Carbon-Molybdenum Steel

Heat to 1350 F., hold 1 hr., furnace cool 50 deg. Fahr. per hr. to 1100 F., remove and cool in still air.

4 to 6 per cent Chromium-Molybdenum Steel

Heat to 1525 F., hold 2 hr., furnace cool not faster than 100 deg. Fahr. per hr. to 1225 F., remove and cool in still air.

Brinell tests after the above heat treatment gave values as follows:

Carbon-molybdenum steel	1½ in. round	—111
	5 in. round	—131
	4½ in. tube	—121
4 to 6 per cent chromium-molybdenum steel	1½ in. round	—139
	5 in. round	—126
	4½ in. tube	—126

McQuaid-Ehn Grain Size:

A standard carburizing test (8 hr. at 1700 F.) was made on specimens from each heat. The grain size readings obtained are as follows:

Carbon-molybdenum steel	1½ in. round	—7 to 8
	5 in. round	—5 to 8
	4½ in. tube	—5 to 8
4 to 6 per cent chromium-molybdenum steel	1½ in. round	—7 to 8
	5 in. billet	—7 to 8
	4½ in. tube	—7 to 8

Both steels may be classified as being of the fine grain type.

Preparation of Material for Testing and Distribution:

One length of carbon-molybdenum steel tube, marked 37239 B4, and one length of 4 to 6 per cent chromium-molybdenum steel tube, marked 57390 B2 were delivered to the Babcock & Wilcox Co. at Barberton. From this material, four 2-ft. bombs of carbon-molybdenum steel, and two 2-ft. bombs of 4 to 6 per cent chromium-molybdenum steel were manufactured by accurately boring and turning the tubes, inserting internal core pieces and welding on spherical heads, for tubular creep tests, Project No. 10.

In addition, tubes were cut into pieces for distribution for other projects. All of these pieces were then carefully heat treated as follows:

Carbon-molybdenum Steel

Heated to 1200 F., held at that temperature for 1¼ hr. and allowed to furnace cool to 180 F. in 27 hr. in an electric muffle furnace.

4 to 6 per cent Chromium-molybdenum Steel

Heated to 1375 F., held at that temperature for 2¼ hr. and furnace cooled to 300 F. in 24 hr.

In heat treating the bombs an atmosphere of nitrogen was maintained throughout the heat treatment, since these were finish machined before heat treating.

The material, after heat treatment, was distributed as follows:

Carbon-molybdenum Steel

Four 2-ft. bombs for Tubular Creep Tests,

One 4½-in. tube, 3 ft. long for tension and relaxation creep tests,

delivered to F. H. Norton, Massachusetts Institute of Technology, for Projects Nos. 10 and 16.

Two 4½-in. tubes, 2 ft. long, delivered to H. W. Gillett, Battelle Memorial Institute, for Projects Nos. 16 and 18.

One 4½-in. tube, 3 ft. long, to C. L. Clark, University of Michigan, for Projects Nos. 14, 16 and 17.

One 4½-in. tube, 3 ft. long to G. W. Wright, for E. L. Robinson, General Electric Co., for Project No. 16.

One piece 4½-in. tube, 3 ft. long, to F. L. Everett, University of Michigan, for Project No. 15.

One 4½-in. tube, 1 ft. long, to H. D. Newell, Babcock & Wilcox Tube Co., for short-time high-temperature tension tests.

One piece, 1 ft., 6 in. long, of 5-in. billet, to F. L. Everett, University of Michigan, for Project No. 15.

Balance of Material on Hand:

Two tubes 20 ft. long, and

One tube 6 ft. long.

4 ft., 9 in., 5-in. diameter billet.

4 to 6 per cent Chromium-molybdenum Steel

Two 2 ft. long bombs for tubular creep tests,

One tube 3 ft. long for creep tests,

delivered to F. H. Norton, Massachusetts Institute of Technology, for tubular tests, Project No. 10 and relaxation creep tests, Project No. 16.

Two pieces of 4½-in. tube, 2 ft. long, to H. W. Gillett, Battelle Memorial Institute, for Projects Nos. 16 and 18.

One piece 4½-in. tube, 3 ft. long, to C. L. Clark, University of Michigan, for Project No. 16 and creep tests.

One piece 4½-in. tube, 3 ft. long, to G. W. Wright, for E. L. Robinson, General Electric Co., for Project No. 16.

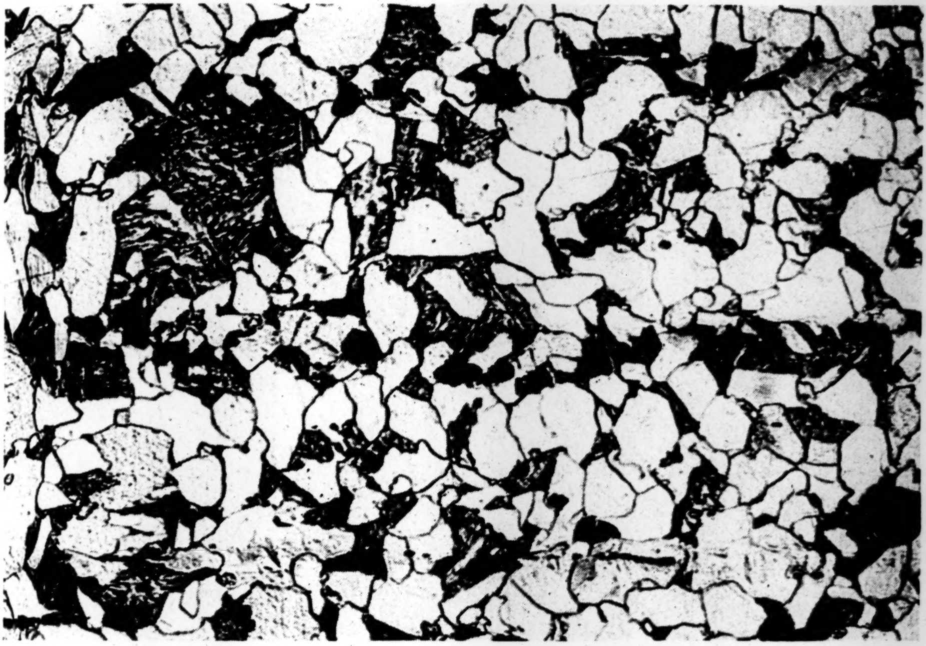
One piece 4½-in. tube, 1 ft. long, to H. D. Newell, Babcock & Wilcox Tube Co., for short-time high-temperature tension tests.

Balance on Hand:

One piece of 4½-in. tube, 20 ft. long, and
One piece 9 ft. long.
One piece of 5-in. diameter billet, 17 ft. long,
Two pieces, 1 ft., 11 in. long, and
One piece 3 ft. long.

In addition, there is available 10 ft. of 1½-in. bar from other heats, of the following analysis:

	Carbon-Molybdenum 1½ in. Heat No. 37012		4 to 6 Chromium-Molybdenum 1½ in. Heat No. 57518	
	Ladle Analysis	Check Analysis	Ladle Analysis	Check Analysis
Carbon, per cent	0.14	0.15	0.12	....
Manganese, per cent......	0.48	0.52	0.43	....
Sulfur, per cent.	0.016	0.019	0.016	....
Phosphorus, per cent......	0.011	0.014	0.018	....
Silicon, per cent	0.15	0.178	0.46	....
Chromium, per cent......	....	....	4.75	....
Molybdenum, per cent......	0.51	0.53	0.58	....



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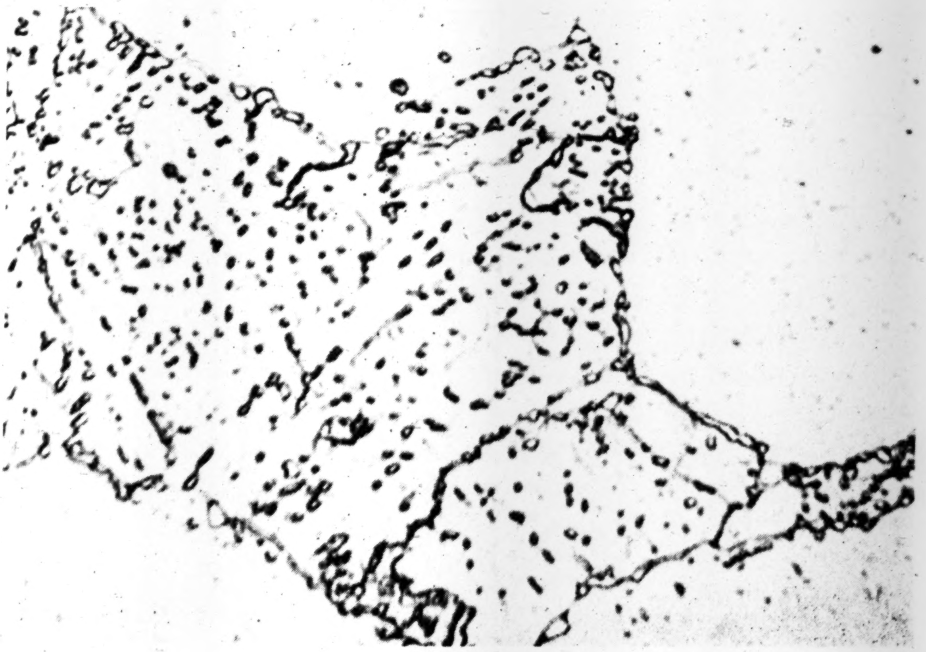

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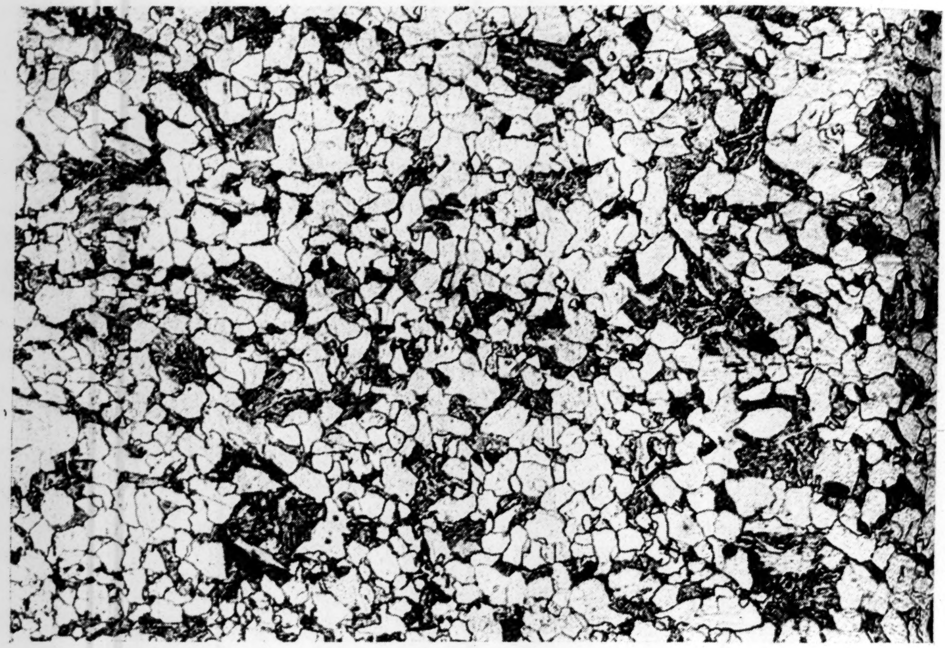
Heat No. 37239, 5-in. Billet.
Etched in Nital.



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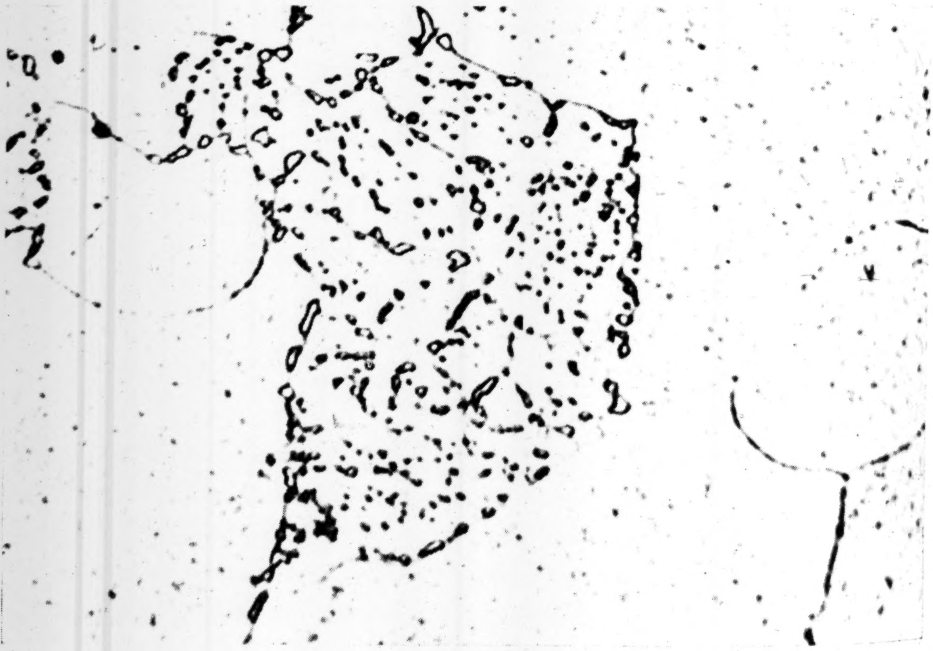

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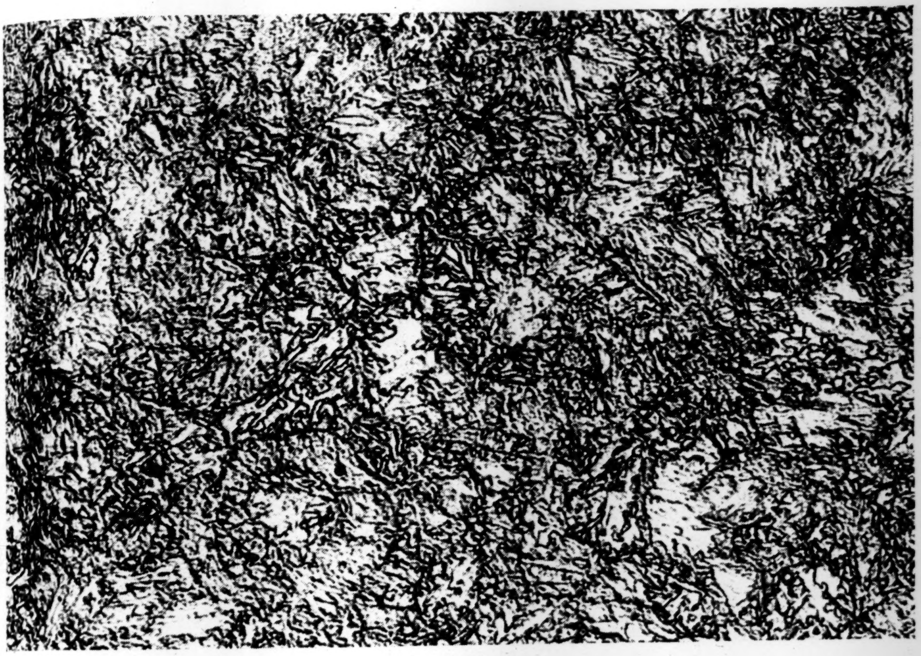
Heat No. 37239, 4½ in. Outside Diameter by ¾-in. Wall Tube.

Etched in Nital.



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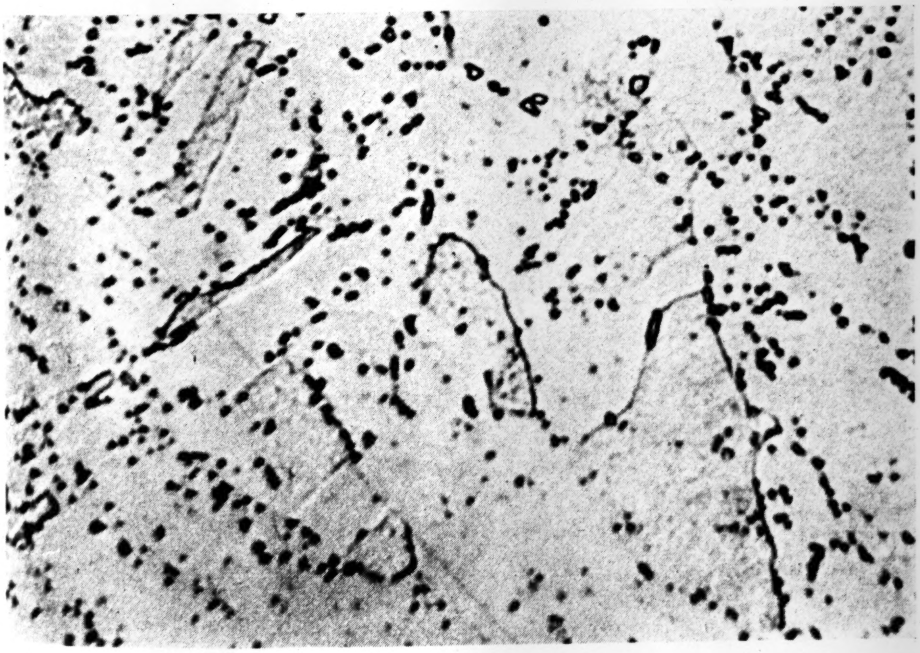

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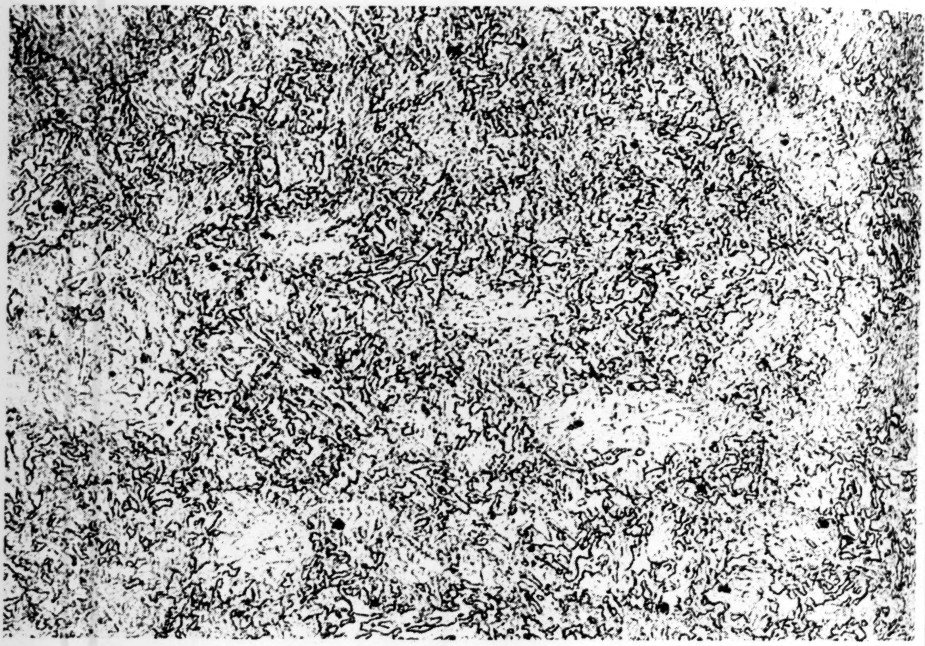

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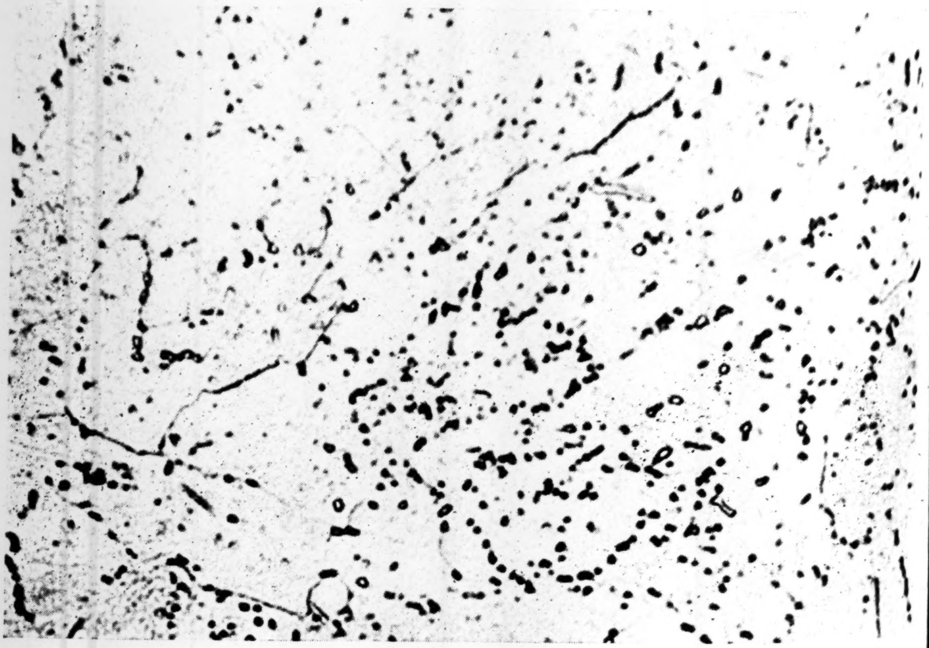

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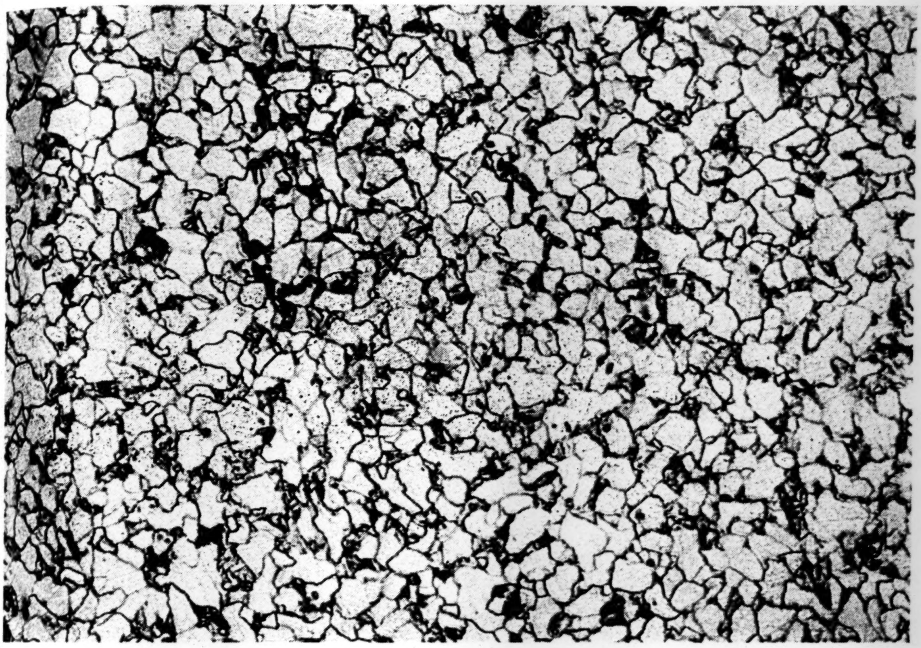

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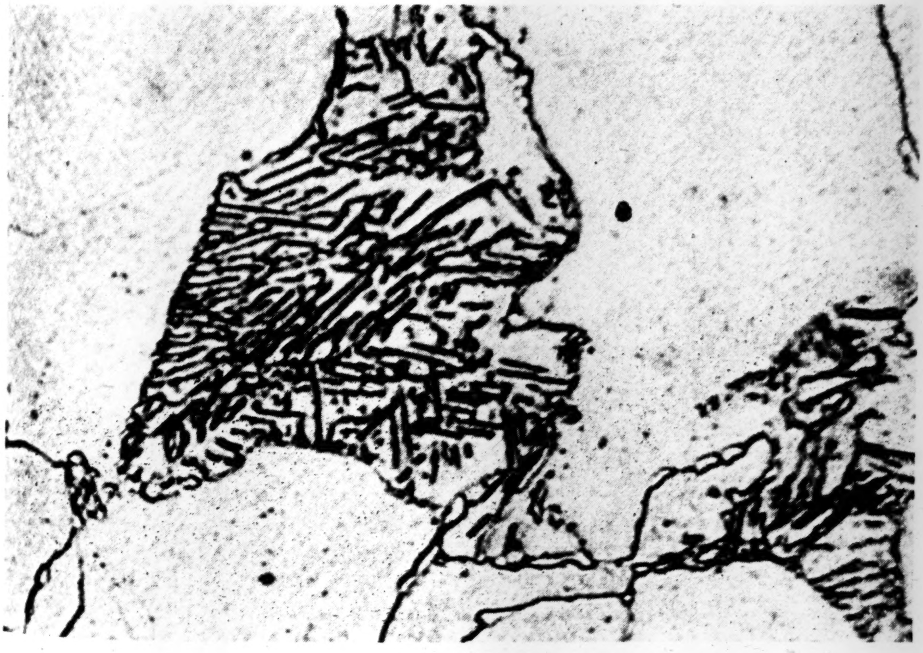

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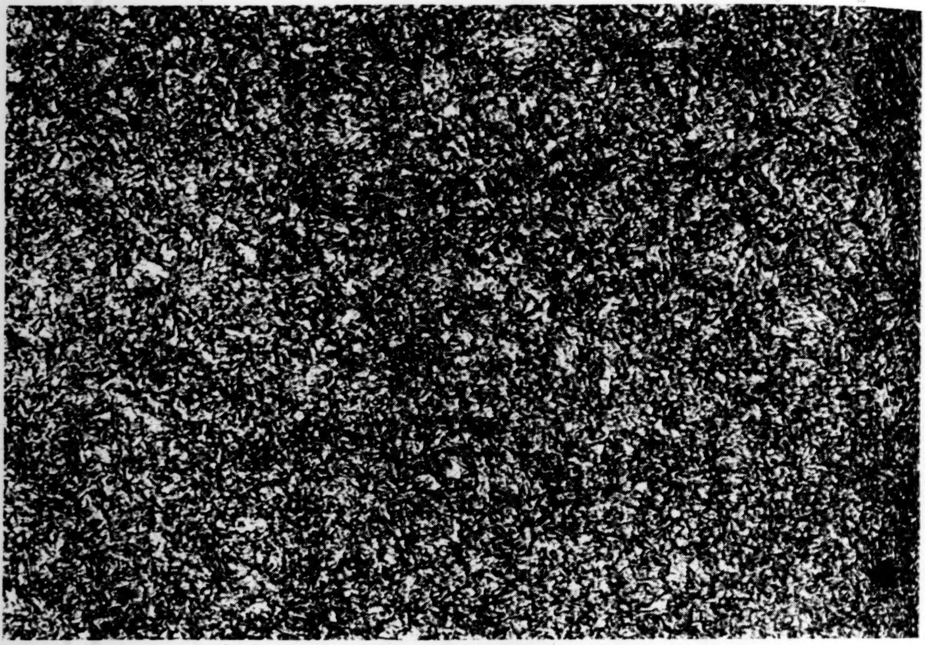

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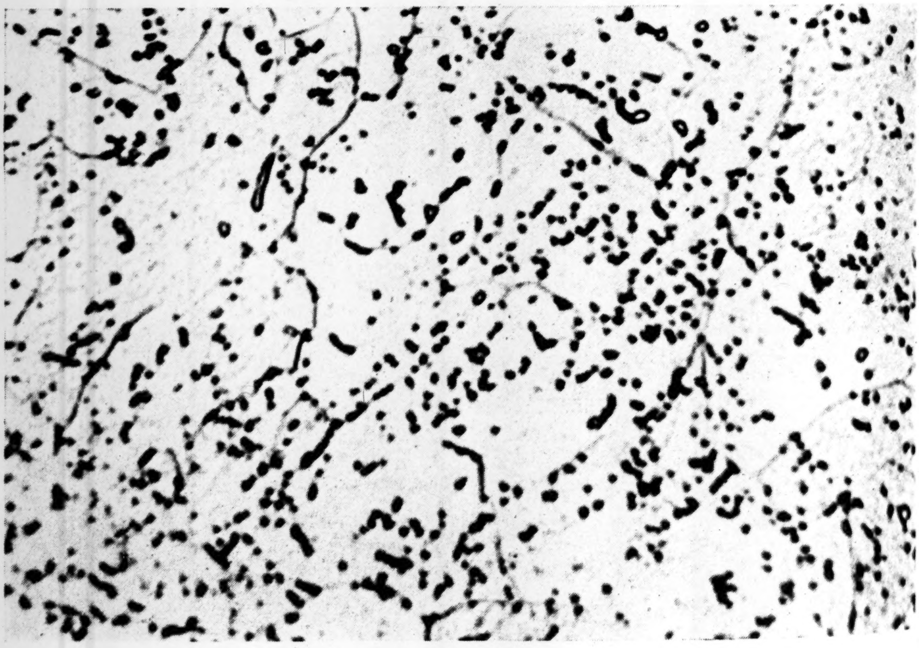

(× 2000)
Heat No. 57518, 1½-in. Billet.
Etched in Nital.

REPORT OF COMMITTEE B-1

ON

COPPER AND COPPER-ALLOY WIRES FOR ELECTRICAL CONDUCTORS

Committee B-1 on Copper and Copper-Alloy Wires for Electrical Conductors held one meeting during the year in Rochester, N. Y., on March 9, 1938.

In the following memorial the committee attempts to express its sorrow and sense of loss in the death of Mr. John A. Capp, chairman of this committee for many years:

> Committee B-1 of the American Society for Testing Materials records with profound sorrow the death of John Allen Capp, on January 6, 1938.
>
> In the passing of John Capp this Society has lost a distinguished and respected collaborator and a sagacious and aggressive leader who made substantial contributions to the purposes of this committee since its inception, and to the general welfare of this Society.
>
> As an engineer and administrator, John Capp showed outstanding executive ability and a thorough understanding of industrial problems. His work was based on a sound scientific background enriched by long and resourceful professional experience in research where his achievements won the merited esteem of his associates in the world of industrial engineering.
>
> As a man, John Capp was open-minded, but of firm convictions which were grounded on his strong character and rugged personality. The example of his life will long be remembered and his memory ever will inspire his associates in this Society to carry on in his resolute spirit.
>
> Through kindly personal contacts he has endeared himself to each member of the committee so that in his passing each member has experienced the loss of a true friend.

A copy of this memorial has been sent to Mrs. Capp at her home in Schenectady, N. Y.

Changes in membership of the committee during the year consist of the following:

G. H. Frank replaces E. W. Larson as representative of the Western Electric Co.,

F. F. Poland replaces E. W. Rouse as representative of the American Smelting and Refining Co.,

T. S. Fuller replaces J. A. Capp as representative of the General Electric Co.,

L. B. Barker has been designated as an additional representative of the General Electric Co.,

C. D. Gray, general interest representative of the American Institute of Electrical Engineers, has resigned. Pending appointment of Mr. Gray's successor, Mr. C. S. Gordon will serve as the sole representative of the A.I.E.E. as well as of the Bell Telephone Laboratories, Inc.,

The Rome Cable Corp., Rome, N. Y., has been added as a producer member of the committee and will be represented by G. E. Rolston,

The Nichols Copper Co., New York City, a producer interest, represented by C. S. Harloff, has been appointed to membership on the committee,

The Delco-Remy Division of General Motors Corp., Anderson, Ind., a consumer interest, has been appointed to membership on the committee with L. W. Murray as representative,

H. H. Wermine, chief engineer of the Belden Manufacturing Co., Chicago, Ill., a consumer interest, has been appointed to membership on the committee.

Committee B-1 consists of 15 producer, 13 consumer, and 2 general interest members, making a total of 30, represented on the committee by 33 individuals.

ACTIVITIES OF SUBCOMMITTEES

Committee B-1 appointed the following new subcommittees to study the projects as outlined below. It is planned that the recommendations of the subcommittees will be available for incorporation in any revisions which it may seem desirable to make next year in the standards under the jurisdiction of the committee, in line with the requirement now appearing in the Regulations of the Society that standards that have stood six years or more without revision shall be reviewed to ascertain whether they are still in accord with present practice:

Subcommittee II (P. H. Grogan, chairman), in cooperation with Committee E-1 on Methods of Testing, was appointed to make recommendations as to modification or amplification of the various standards under the jurisdiction of Committee B-1 in order to provide proper limitations on speed of testing for acceptance tests. Standards for trolley wire tests are excepted from the scope of this subcommittee. To make this information available to the industry at the earliest possible time the committee is recommending the immediate inclusion of such information in notes to be added to the various copper wire specifications as indicated in detail later in this report.

Subcommittee III (T. S. Fuller, chairman) was appointed to investigate the requirements for packaging of wire appearing in the Standard Specifications for Soft or Annealed Copper Wire (B 3 – 27) and to determine whether the provisions are in accord with present practice.

Subcommittee IV (J. R. Becker, chairman) will review the Standard Specifications for Soft Rectangular Copper Wire (B 48 – 27) and request comments from consumer interests who use this standard.

Subcommittee V (P. H. Grogan, chairman), was appointed to review the Standard Specifications for Hot-Rolled Copper Rods for Wire Drawing (B 49 – 26) and to consider especially the dimensional tolerances.

Subcommittee VI (W. R. Hibbard, chairman) will investigate and recommend any desirable change in the length of lay limitation in the Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (B 8 – 36). At the present time this standard calls for a lay of not less than 10 nor more than 16 times the outside diameter of the layer of wires under consideration. It may possibly be that more restrictive specifications are desirable for cable made of a small number of wires than when a larger number of wires are used.

Subcommittee VII (R. S. Pratt, chairman), was appointed to collaborate with Subcommittee II and Committee E-1 in an investigation of the effect of speed of application of load in testing trolley wire, with particular reference to the Standard Specifications for Bronze Trolley Wire (B 9 – 37), and for Copper Trolley Wire (B 47 – 37).

Subcommittee VIII (W. H. Bassett, Jr., chairman) will report on desirable rope-lay construction which may be added to the Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (B 8 – 36), or which might form the subject of another specification contemplating rope-lay cable as contrasted to the concentric-lay cable in Specifications B 8.

Subcommittee IX (G. E. Dean, chairman) was appointed to report on a satisfactory modification of the wording of the inspection clause in Section 10 of Specifications B 8.

RECOMMENDATIONS AFFECTING STANDARDS

Revision of Tentative Standard:

Tentative Specifications for Hard-Drawn Copper Alloy Wires for Electrical Conductors (B 105 – 37 T).[1]—The committee's attention has been called to the fact that in these specifications the maximum resistivity values given in Section 8 for Grades 9, 13 and 15 are incorrect. The error apparently has been occasioned by not taking into account the lower density of these three alloys as compared with copper. Also, it has been reported that in actual practice Grade 9 of these specifications has a conductivity of about 8.5 instead of 9.0, and also the tensile strength for this grade is about 5000 lb. per sq. in. less than that given in Table I of the specifications. In addition, the producers of Grade 15 alloy wire desire to eliminate the copper-tin type of alloy for this grade, which eliminates in Section 10 the value of 8.89 g. per cu. cm. for density for this grade and makes necessary a slight change in the explanatory note under this grade. The committee therefore recommends that Tentative Specifications B 105 be revised as follows and continued as tentative:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 693 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 400.

Section 3.—In the second sentence change "Grades Nos. 9 to 85" to read "Grades Nos. 8.5 to 85," and in the list following this sentence change "Grade No. 9" to read "Grade No. 8.5."

Table I.—Under Tensile Strength change the heading of the column "Grades Nos. 9 and 13" to read "Grade No. 13" and add a separate column for Grade No. 8.5 to read as follows:

DIAMETER, IN.	TENSILE STRENGTH, MIN., LB. PER SQ. IN. GRADE NO. 8.5
0.2893	97 500
0.2576	103 800
0.2294	107 500
0.2043	110 200
0.1819	112 200
0.1620	114 000
0.1443	115 300
0.1285	116 600
0.1144	117 800
0.1019	118 900
0.09074	119 800
0.08081	120 600
0.07196	121 200
0.06408	121 700
0.05707	122 200
0.05082	122 500
0.04526	122 800
0.04030	123 000
0.03589	123 200
0.03196	123 500

Section 8.—Change the values of maximum resistivity to read as follows by the addition of the italicized figures and the omission of those in brackets:

GRADE	MAXIMUM RESISTIVITY, POUNDS PER MILE OHM	MAXIMUM RESISTIVITY, OHMS PER CIRCULAR MIL FOOT
No. [9] *8.5*	[9 724] *10 169*	[115.22] *122.00*
No. 13	[6 732] *6 649*	79.78
No. 15	[5 835] *5 605*	69.14
No. 20	4 376	51.86
No. 30	2 917	34.57
No. 40	2 188	25.93
No. 55	1 591	18.86
No. 65	1 346	15.96
No. 80	1 094	12.96
No. 85	1 030	12.20

Section 10.—Change the table of density values to read as follows by the addition of the italicized figures and the omission of the words and figures in brackets:

GRADE	DENSITY
Nos. [9] *8.5* and 13	8.78 g. per cu. cm. (0.3172 lb. per cu. in.)
No. 15[a]	8.54 g. per cu. cm. (0.3085 lb. per cu. in.) [8.89 g. per cu. cm. (0.3212 lb. per cu. in.)]
Nos. 20, 30, 40, 55, 65, 80 and 85	8.89 g. per cu. cm. (0.3212 lb. per cu. in.)

[[a] The lower density value shall be used for alloys of the copper-tin-aluminum type. The higher density value shall be used for the copper-tin alloys.]

Section 12. (a). —Change to read as follows by the omission of the word in brackets:

12. (*a*) Package sizes for [round] wire shall be agreed upon in the placing of individual orders.

Explanatory Note.—In the table change Grade No. "9" to read "8.5." Under Grade No. 15 delete the copper-tin alloy.

Add the following as Note 2, designating the present note as Note 1:

NOTE 2.—It is known that the rate of loading during tension testing of copper and copper alloys affects the performance of the sample to a greater or lesser extent, depending upon many factors. In general, tested values of tensile strength are increased and elongation values are reduced with increase of speed of the moving head of the testing machine. These effects are pronounced when the speed of the moving head is excessive in the tension testing of hard-drawn and medium-hard-drawn copper and copper-alloy wires. Pending the availability of more adequate information, it is suggested that tests on wire be made at speeds of moving head which under no-load conditions are not greater than 3 in. per min.

Revisions of Standards:

The committee recommends for immediate adoption, revisions in the following seven specifications, and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that these modifications may be referred to letter ballot of the Society:

Standard Specifications for Hard-Drawn Copper Wire (B 1 – 27):[1]

Explanatory Notes.—Add a new Note 5 to read the same as Note 2 which is recommended above to be added to Tentative Specifications B 105 – 37 T.

Standard Specifications for Medium-Hard-Drawn Copper Wire (B 2 – 27):[2]

Table I.—In order to render the table of tensile strengths consistent, change the minimum value of wire 0.182 in. in diameter from "48,600" to read "48,660."

Explanatory Notes.—Add a new Note 6 to read the same as Note 2 which is recommended above to be added to Tentative Specifications B 105 – 37 T.

Standard Specifications for Soft or Annealed Copper Wire (B 3 – 27):[3]

Explanatory Notes.—Add a new Note 6 to read as follows:

NOTE 6.—In general, tested values of tensile strength are increased and elongation values are reduced with increase of speed of the moving head in the tension testing of copper wire. In the case of tests on soft or annealed copper wire, however, the effects of speed of testing are not pronounced. Tests of soft wire made at speeds of moving head which under no-load conditions are not greater than 12 in. per min. do not alter the final results of tensile strength and elongation determinations to any practical extent.

Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 – 21):[4]

Explanatory Note.—Designate the present note as Note 1 and add a new Note 2 to read the same as Note 6 which is recommended above to be added to Standard Specifications B 3.

Standard Specifications for Soft Rectangular Copper Wire (B 48 – 27):[5]

Explanatory Notes.—Add a new Note 5 to read the same as Note 6 which is recommended above to be added to Standard Specifications B 3.

Standard Specifications for Bronze Trolley Wire (B 9 – 37),[6] *and for Copper Trolley Wire (B 47 – 37):*[6]

Explanatory Note.—At the end of each of these specifications add the following as an explanatory note:

NOTE.—It is known that the rapidity with which load is applied to a sample during tension testing affects the performance of the sample to a greater or lesser extent, depending upon many factors. In general, tested values of tensile strength are increased and elongation values are reduced with increase of speed of the moving head of the testing machine. However, there are speeds below which no practical change is observable. Pending the time when more adequate information is available, it is suggested that tests on trolley wire be made at moving head speeds which under no-load conditions are not greater than 3 in. per min. No minimum restriction on speed of testing seems necessary.

New Tentative Standard:

Tentative Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft:

The committee has considered the recommendations of Subcommittee I on Electric Transmission Wire and Cable Specifications (G. E. Dean, chairman) that the Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard, or Soft (B 8 – 36)[7] be modified to make this standard sufficiently inclusive to warrant the withdrawal of the Tentative Specifications for Hard-Drawn Copper Transmission Cable (B 87 - 32 T) as recommended later in this report. In view of certain questions still not completely solved, it seems best to recommend that the present standard specifications as modified be designated as tentative for one year, the present standard specifications remaining as standard. The new Tentative Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard, or Soft, as appended hereto,[1] incorporate the changes, an explanation of which is given below.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 655.

[2] *Ibid.*, p. 660.

[3] *Ibid.*, p. 665.

[4] 1936 Book of A.S.T.M. Standards, Part I, p. 669.

[5] *Ibid.*, p. 674.

[6] 1937 Supplement to Book of A.S.T.M. Standards, pp. 32, 38.

[7] 1936 Book of A.S.T.M. Standards, Part I, p. 638.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. REVISION OF TENTATIVE STANDARD			
Specifications for Hard-Drawn Copper Alloy Wires for Electrical Conductors (B 105 - 37 T)	18	0	5
II. REVISIONS OF STANDARDS			
Specifications for Hard-Drawn Copper Wire (B 1 - 27), immediate adoption	23	0	0
Specifications for Medium-Hard-Drawn Copper Wire (B 2 - 27), immediate adoption	23	0	0
Specifications for Soft or Annealed Copper Wire (B 3 - 27), immediate adoption	23	0	0
Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 - 21), immediate adoption	23	0	0
Specifications for Soft Rectangular Copper Wire (B 48 - 27), immediate adoption	22	0	1
Specifications for Bronze Trolley Wire (B 9 - 37), immediate adoption	18	0	5
Specifications for Copper Trolley Wire (B 47 - 37), immediate adoption	18	0	5
III. NEW TENTATIVE STANDARD			
Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft	21	2	5
IV. WITHDRAWAL OF TENTATIVE STANDARD			
Specifications for Hard-Drawn Copper Transmission Cable (B 87 - 32 T)	20	0	3

In order to clarify misunderstandings which have arisen concerning the joints or brazes in wire, Section 3 has been revised as shown in the appended specifications. This modification does not in fact change the sense of this section to any great extent, but makes it unmistakable in meaning and more inclusive in scope.

A revision in Section 4 on lay or pitch is being made to indicate definitely that left-hand lay shall be furnished unless otherwise specified by the purchaser. It is felt that there is considerable advantage to all parties concerned if the lay is made definitely one hand or another rather than to leave the matter indefinite, as has been the case heretofore.

It has come to the committee's attention that there may be some misunderstanding in Section 6 (*a*) as to what is meant by the provision that the minimum elongation permitted shall be reduced 5 per cent in the case of wires removed from completed cable. To clarify this the following parenthetical expression is being inserted at the end of the second sentence of this section: "(For example, from 30 per cent to 25 per cent.)." The optional construction in former Table I of these specifications is being eliminated and the table renumbered as Table II. The only other change in the table is in Class *A* cable of 211,600 cir. mil and 167,800 cir. mil where 12 wires are now required with corresponding changes in diameter, and the inclusion of a footnote stating that the prevailing practice in the industry for these two sizes is to supply 7-wire (Class *AA*) cables for gages Nos. 000 and 0000 weather-resisting (weatherproof) conductors, unless the application requires a more flexible stranding.

A new Paragraph (*e*) is being added to Section 6 to provide for certain tests requested by a few purchasers involving the testing of hard-drawn wires removed from completed cable. Section 9 is being revised to indicate limits on variations in lengths of wire supplied under the specifications and to include requirements for marking. The inspection requirements in Section 10 are being changed to require all inspection and testing to be made at the place of manufacture unless otherwise especially agreed upon between the manufacturer and purchaser at the time of purchase. Three additional explanatory notes are being added to the specifications, including a table of suggested package lengths for hard and medium-hard Class *AA* cable.

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[1] See p. 677.

Withdrawal of Tentative Standard:

Tentative Specifications for Hard-Drawn Copper Transmission Cable (B 87 - 32 T).[1] —In view of the fact that the Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (B 8 - 36) when revised as recommended above will include desirable provisions of Tentative Specifications B 87 - 32 T, there seems to be no further need for these latter specifications and the committee accordingly recommends that they be withdrawn.

The above recommendations have been submitted to letter ballot of the committee, which consists of 30 members, the results being shown in Table I.

Committee B-1 has elected the following officers for the ensuing two-year term:

Chairman, J. H. Foote
Vice-Chairman, W. H. Bassett, Jr.
Secretary, G. E. Dean

This report has been submitted to letter ballot of the committee, which consists of 30 members; 28 members returned their ballots, of whom 25 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

W. H. BASSETT, JR.,
Vice-Chairman.

J. H. FOOTE,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 666 (1932); also 1937 Book of A.S.T.M. Tentative Standards, p. 405.

REPORT OF COMMITTEE B-2
ON
NON-FERROUS METALS AND ALLOYS

No general meeting of Committee B-2 on Non-Ferrous Metals and Alloys has been held in the interval between the annual meetings of the Society in 1937 and 1938. However, several of the subcommittees have had one or more meetings at which the business outlined below has been transacted.

Activities of Subcommittees

Subcommittee I on Refined Copper (H. C. Jennison, chairman).—This subcommittee met on February 18, 1938, at which time proposed specifications for electrolytic cathode copper were discussed and reduced to draft form. At a second meeting on March 25, attended by members (or proxies) representing all the large producers and consumers, the specifications were accepted unanimously. Subsequent to that date, copies of the specifications were sent to all members of the subcommittee and no criticism was received. It is accordingly recommended that the proposed Tentative Specifications for Electrolytic Cathode Copper, appended hereto, after approval by Committee B-2, be submitted to the Society through Committee E-10 on Standards for acceptance for publication as tentative.[1]

Subcommittee II on Refined Lead, Tin, Antimony and Bismuth (T. A. Wright, chairman).—An active group of this subcommittee has been studying copper-bearing lead for the manufacture of sheath for electrical cables. At meetings on March 10 and May 3, 1938, certain changes in the Standard Specifications for Pig Lead (B 29 – 35) were considered but no definite decision has as yet been reached.

A special group under the chairmanship of D. L. Ogden has been studying the situation regarding tin. It reports that in view of the fact that less than 1 per cent of the tin produced in the world is of domestic origin, and that on the other hand, the United States consumes approximately 45 per cent of the tin produced, there would be little warrant in setting up specifications as to composition and form. It is just as certain, however, that there is a demand for specifications to cover the sampling of tin and its chemical and spectrochemical analysis.

Subcommittee III on White Metal Alloys (G. H. Clamer, chairman).—This subcommittee has under consideration the following points in connection with the Standard Specifications for Solder Metal (B 32 – 21): (1) Study of the effect of bismuth, information on which is not well defined; (2) study (with the aid of Committee E-3 on Chemical Analysis of Metals) of the methods of sampling and chemical analysis; and (3) deletion of reference to the use of "virgin metals" in Class A and Class B solder. No recommendation for action is made at this time.

Subcommittee V on Precious Metals and Alloys (R. H. Leach, chairman).—This subcommittee reports that a large amount of work has been done in the chairman's laboratory on the liquidus diagram of the silver-copper-zinc alloys, and recommends that a revised diagram based on this work replace Fig. 1 now appearing in the appendix to the Standard Specifications for Silver Solders (B 73 - 29). Since the changes are not of considerable magnitude it is believed that this is an editorial matter not requiring a letter ballot of the committee.

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[1] See Editorial Note, p. 190.

Subcommittee VII on Refined Nickel and High Nickel Alloys, Cast and Wrought (C. E. Margerum, chairman).—This subcommittee has drafted proposed tentative specifications for nickel-copper alloy plates, sheets and strips. These represent the culmination of more than five years of negotiation, in order to harmonize the interests of the U. S. Navy (one of the chief consumers) and the principal producers of monel metal, especially as to standards of quality and dimension. It was believed to be acceptable to all interested parties but after consideration by the main committee they were referred back to the subcommittee for further study.

Subcommittee VIII on Miscellaneous Refined Metals and Alloys (E. E. Schumacher, chairman).—This subcommittee has critically examined each of the four specifications under its jurisdiction and has unanimously approved revisions of these specifications as outlined below, and the reversion of the specifications to the tentative status. After approval by Committee B-2 these recommendations are to be submitted to the Society through Committee E-10 on Standards.[1]

Standard Specifications for Phosphor Tin (B 51 - 27):[2]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

> 2. The manufacturer shall use [new] *pure or refined* tin of uniform quality throughout in the manufacture of phosphor tin.

Section 6.—Change the second sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

> The ingots selected shall be drilled *or sawed* completely through, or one-half through from top [to] *and* bottom, the surface material being rejected.

Standard Specifications for Phosphor Copper (B 52 - 27):[3]

Section 2.—Change from its present form: namely,

> 2. The manufacturer shall use new metal or new metal and scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.

to read as follows:

> 2. The manufacturer shall use pure or refined metal, with or without the addition of scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.
>
> NOTE.—For the quality of copper to be used reference should be made to the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5) of the American Society for Testing Materials.

Section 6.—Change the second sentence to read as follows by the addition of the italicized words:

> The ingots selected shall be drilled *or sawed* completely through, or one-half through from top and bottom, the surface material being rejected.

Section 7.—Change the first sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

> A brand and melt number shall be cast or otherwise plainly marked upon each slab, [or] ingot, *or container* by which the manufacturer and heat may be identified.

Standard Specifications for Silicon Copper (B 53 - 27):[4]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] See Editorial Note, p. 190.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 722.

[3] 1936 Book of A.S.T.M. Standards, Part I, p. 720.

[4] *Ibid.*, p. 724.

1. These specifications cover silicon copper in [one grade] *three grades as follows: Grade A, Grade B, Grade C.*

Section 2.—Change from its present form: namely,

2. The manufacturer shall use new metal, or new metal and scrap resulting from the manufacture of ingots of similar composition in the manufacture of this material.

to read as follows:

2. The manufacturer shall use pure or refined metal, with or without the addition of scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.

NOTE.—For the quality of copper to be used reference should be made to the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5) of the American Society for Testing Materials.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Specifications for Electrolytic Cathode Copper	49	0	21
II. REVERSION OF STANDARDS TO TENTATIVE			
Specifications for Phosphor Tin (B 51 – 27), as revised	44	0	26
Specifications for Phosphor Copper (B 52 – 27), as revised	49	0	22
Specifications for Silicon Copper (B 53 – 37), as revised	48	0	23
Specifications for Brazing Solder (B 64 – 28), as revised	49	0	23

Section 3.—Change to read as follows by the addition of the italicized word:

3. The manufacturer or vendor shall furnish silicon copper in the form of *lumps*, ingots, or notched slabs of such size that they can be handled conveniently.

Section 5.—Change to read as follows by the addition of the italicized words and figures:

5. The material shall conform to the following requirements as to chemical composition:

	Grade A	*Grade B*	*Grade C*
Silicon, per cent	10 to 12	*17 to 21*	*28 to 32*
Tin, maximum, per cent	0.25	*0.25*	*0.25*
Zinc, maximum, per cent	0.25	*0.25*	*0.25*
Iron, maximum, per cent	0.75	*0.750*	*0.750*
Aluminum, maximum, per cent	0.25	*0.25*	*0.25*
Copper, per cent	remainder	*remainder*	*remainder*

The sum of the copper, silicon and iron content shall be not less than 99.4 per cent.

Section 6.—Change the second sentence to read as follows by the addition of the italicized words:

The ingots selected shall be drilled *or sawed* completely through, or one-half through from top and bottom, the surface material being rejected.

Section 7.—Change the first sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

[A] *The* brand and melt number shall be cast or otherwise plainly marked upon each slab, [or] ingot, *or container* by which the manufacturer and heat may be identified.

Standard Specifications for Brazing Solder (B 64 – 28):[1]

Section 2.—Change to read as follows by the addition of the italicized word and the omission of the word in brackets:

2. These solders shall be [produced] *prepared* by grinding or other process of granulation.

Section 9.—Change to read as follows by the addition of the italicized word and figure and the omission of the word and figure in brackets:

9. Round and long grain solder shall be packed in strong wooden boxes, not to exceed [200] *300* lb. per box. The fine grain solders shall be packed in paper-lined wooden boxes. Lots weighing less than 100 lb. shall be packed

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 688.

in [tin] *tinned* containers, enclosed in wooden boxes unless otherwise specified.

Section 10.—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

> 10. Lump solder shall be packed in strong barrels *or boxes,* not to exceed 500 lb. per [barrel] *container.*

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 95 members; 79 members returned their ballots, the results being shown in Table I.

This report has been submitted to letter ballot of the committee which consists of 95 members; 79 members returned their ballots, of whom 62 have voted affirmatively and 4 negatively.

Respectfully submitted on behalf of the committee,

R. F. MEHL,
Chairman.

E. E. THUM,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee B-2 on Non-Ferrous Metals and Alloys presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Specifications for Electrolytic Cathode Copper.

Reversion to tentative and revision of Specifications for:

- Phosphor Tin (B 51 – 27),
- Phosphor Copper (B 52 – 27),
- Silicon Copper (B 53 – 27), and
- Brazing Solder (B 64 – 28).

These recommendations were accepted by Committee E-10 and appear on pp. 683, 709, 711, 713, and 707, respectively.

REPORT OF COMMITTEE B-3
ON
CORROSION OF NON-FERROUS METALS AND ALLOYS

Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys held two meetings during the year: one in New York City on June 30, 1937, and one in Rochester, N. Y., on March 9, 1938.

In the following brief words this committee attempts to express its sorrow and sense of loss in the death of Mr. C. L. Hippensteel, for many years chairman of Subcommittee VIII:

> With profound appreciation of his sterling worth, Committee B-3 of the American Society for Testing Materials records with deep sorrow the death of Claude Lorraine Hippensteel on September 20, 1937.
>
> In the passing of "Hipp" this Society, and especially this committee, has lost one of its most able and most enthusiastic members. He gave unstintingly of his time and energy for the general good of the Society, and he will long be remembered with affection by those who knew him.

The committee has been active during the past year through its Subcommittees III on Spray Test, VI on Atmospheric Corrosion, and VIII on Galvanic and Electrolytic Corrosion in carrying forward the programs under the sponsorship of these subcommittees.

Subcommittees II on Alternate Immersion Test, IV on Definitions, and V on Accelerated Electrolytic Test have been inactive during the past year.

At the March meeting of Committee B-3, Subcommittee VII on Corrosion in Liquids was disbanded and Subcommittee I on Total Immersion Test was instructed to take over the work of Subcommittee VII. Subcommittee I has been inactive during the past year but is now preparing a program which will include the work previously carried out by Subcommittee VII.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee III on Spray Test (E. H. Dix, Jr., chairman).—This subcommittee has continued its study of methods of making salt-spray tests. The subcommittee met in Rochester, N. Y., on March 8 to discuss the draft of a proposed method of test but concluded that the revisions that were necessary were sufficiently extensive to make its publication this year inadvisable. The revised draft is being considered further with the hope that it may be published as information during the coming year.

Subcommittee VI on Atmospheric Corrosion (W. H. Finkeldey, chairman).—This subcommittee reported in 1933[1] and 1935[2] the results of the first two inspections and series of atmospheric corrosion tests on 24 non-ferrous metals and alloys after exposures of 1 yr. and 3 yr., respectively, at nine test sites. This program of atmospheric exposure of these various materials has continued and a similar report covering the third inspection and series of tests after 6 yr. has been prepared by the subcommittee as appended hereto.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 234 (1933).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 142 (1935).

Subcommittee VII on Corrosion in Liquids (A. J. Phillips, chairman).—This subcommittee presents its final report as follows:

In the 1932 report[1] of the committee the program of liquid corrosion tests proposed by Subcommittee VII was given, including a detailed outline of the metals to be tested, the solutions, form of specimens, and test racks. The 1934 report[2] included the first corrosion data together with a description of the actual racks used for the salt, caustic soda, and sulfuric acid tests. This early report also included, in addition, corrosion test results after exposures of several sets of specimens to sulfuric acid in three different locations.

In 1935[3] test data were presented giving results on one set of specimens exposed to salt water corrosion, on three sets of specimens exposed to sodium hydroxide, and on one additional set of specimens exposed to sulfuric acid solutions. At that time it was anticipated that tests in hydrochloric acid would be initiated immediately. However, it was soon found that a suitable source of reasonably uncontaminated hydrochloric acid could not be found unless the committee was willing to guarantee that such acid would not be seriously contaminated by the specimens. Preliminary tests were performed which indicated that many of the specimens outlined for testing in hydrochloric acid were quite unsuitable for this medium and would seriously contaminate any hydrochloric acid test liquid to which they were exposed. As a result of this condition, it was felt that the test procedure outlined for hydrochloric acid could not be adhered to and would have to be abandoned.

The tests scheduled for sulfuric acid and sodium hydroxide have been for all practical purposes completed. Specimens, which were exposed to a saturated sodium chloride solution in a salt grainer, showed that there was practically no corrosion when so tested in pure salt solutions and that corrosion data would not be forthcoming in this medium in any reasonable period of time. The test samples exposed to sea salt show attack as reported in 1935, but as this test procedure would not give duplicable results from time to time, it was felt that repeated tests with this medium were hardly justified. As a result the Advisory Committee has decided that Subcommittee VII has completed, in so far as it is practical, the work outlined for it, and should, therefore, be disbanded.

Subcommittee VIII on Galvanic and Electrolytic Corrosion (L. J. Gorman, chairman).—This subcommittee has continued its test program and a report containing data obtained from these studies should be available next year.

The couples remaining on test will have completed a 7-yr. period of exposure at the end of this summer. It is planned to bring in for inspection the two sets of couples (C and D) at all locations remaining on test at the end of 7 yr. One set of couples (D, for example) from each location is to be repaired where necessary and returned to location if the condition of the couples warrants this action. Couples of this set that are not worth returning are to be eliminated from the tests and final disposition made. The other set is to be broken down, examined, cleaned, and weighted in accordance with the established procedure.

It is expected that arrangements can be made to have the cleaning and weighting of the disks done under the direction of the Bell Telephone Laboratories, personnel so that the procedure will be identical with that followed in the examination of the previous couples.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 243 (1932).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 222 (1934).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 160 (1935).

A meeting of Subcommittee VIII will be called when the couples have been assembled and before they are broken down for the purpose of inspection and to determine which couples are to be returned to location.

Difficulties have developed in connection with the proposed program of immersion tests of galvanic couples in sulfuric acid, sodium hydroxide, and hot water. No work will be done on these tests until suitable tests sites can be located and a sealing compound found that will withstand these immersions.

Subcommittee VIII has now approved a program of tests to be made in sea water at Wilmington, N. C. The initial tests are to be of a preliminary nature to obtain information on the best way to make the tests, particularly as to mounting the specimens, the effect of barnacles and marine growth, and other factors influencing the tests. The effect on marine growth of starting the tests in the summer or fall is to be determined, and the shape or form of the specimens is to be reconsidered. A few selected couples, made up in two sets, are to be used initially and tested under different conditions at Wilmington. The period over which these tests will run is left to the judgment of the group assigned to do the work, but will not exceed one year. This group will work out the details, conduct the preliminary tests, and report back to the committee. It was considered advisable to make the final tests at other representative locations and, while the preliminary work is under way, consideration is to be given to the selection of two other locations; Key West, Fla., and Portsmouth, N. H., were mentioned.

A program of atmospheric exposure tests of stainless steel couples is being planned. For the stainless steel portion of the couples the following materials will be included:

16 to 18 per cent chromium alloy steel,
18 per cent chromium, 8 per cent nickel alloy steel, low carbon, annealed, and
18 per cent chromium, 8 per cent nickel alloy steel, low carbon, rolled to approximately 150,000 lb. per sq. in.

The other electrode will be the regular series of non-ferrous metals included in the previous test conducted by Subcommittee VIII, as follows:

Aluminum (99.1 + per cent)
Zinc (99.0 + per cent) Tin (99.8 + per cent)
Iron (mild steel) Nickel (99.3 per cent)
Lead (99.9 + per cent) Copper (99.9 per cent)

The general form of specimen used previously, consisting of flat washers with bakelite insulated bushings, will be incorporated in this new series of tests.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 54 members; 48 members returned their ballots, of whom 46 have volted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

T. S. FULLER,
Chairman.

SAM TOUR,
Secretary.

REPORT OF SUBCOMMITTEE VI ON ATMOSPHERIC CORROSION OF NON-FERROUS METALS AND ALLOYS

This report presents the results of the third series of tests made on 24 non-ferrous metals and alloys[1] exposed in 1931 to various atmospheres at nine test locations. The program of the subcommittee contemplates making five such tests at various intervals of time over a 25-yr. period. In all, three sets of tests have been made to date after exposure intervals of approximately 1 yr., 3 yr.[2] and 6 yr.

The extent of corrosion was determined by the same procedure used in the previous tests, namely, by measuring the changes in weight of duplicate 9 by 12-in. plate specimens, by visual examination of these plate specimens, and by determining the changes in tensile strength and percentage elongation of tension test specimens.

The exposure periods at the various test locations for the plate and tension specimens are given in Table I. The time intervals are different for the plate and tension specimens because the exposure of the former is interrupted for a few months each time the plate specimens are removed from the rack for inspection, while the exposure of tension specimens is continuous.

Attention is called to the fact that both the plate and tension specimens at the Pittsburgh test location (Brunot Island) were immersed under about 10 ft. of water for several days during March, 1936, owing to the extraordinary flood conditions prevailing in the Ohio River valley at that time. Shortly after the flood had subsided, all the plate and tension specimens were removed from the racks and carefully washed in clear water. Any specimens showing evidence of the deposition of oil, grease or tarry matter were also washed in gasoline. The specimens were then immediately returned to the racks for further exposure.

This accidental submersion in water and the necessary subsequent cleaning treatments does not appear to have had any marked effect on the corrosion of the various metals and alloys in so far as this is indicated by changes in weight or tensile properties. However, the corrosion product films of several of the metals and alloys are of a different color from those normally found on such materials in the Pittsburgh atmosphere.

The ultimate effect of this circumstance on the corrosion rate of the metals and alloys is uncertain, and due consideration should be given to the foregoing in interpreting the data from this test location.

Change in Weight Tests:

The 9 by 12-in. plate specimens were weighed without attempting to remove any accumulation of corrosion products, which is in accordance with the procedure followed in making the previous weight tests. The weight determinations were made by the Division of Metallurgy of the National Bureau of Standards using a balance sensitive to 0.1 mg., but the weights of the plate specimens are reported only to 0.01 g. In general, the agreement in the weight changes on the duplicate specimens is good when consideration is given to the fact that these weights are determined on uncleaned specimens.

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[1] A full description of the metals and alloys included in these tests, giving chemical composition, mechanical properties and microstructure, appears in the 1932 report of Committee B-3, *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 214 (1932).

[2] The results of previous tests, made after 1-yr. and 3-yr. exposures, are given in the 1933 and 1935 reports of Committee B-3, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 234 (1933); also Vol. 35, Part I, p. 142 (1935).

The subcommittee has not as yet adopted standard units for reporting weight changes, and, therefore, only the total weight changes in grams for each 9 by 12-in. plate specimen, prefixed by a plus or a minus sign to indicate a gain or loss, are given in the tabulations of data.

Since the weight changes are determined on uncleaned specimens and since about one-half of the weight changes are still "gains," after 6-yr. exposure, no accurate determination of the corrosion rate can be made at this time for most of the materials. In fact, in several cases such determinations may be actually misleading. Furthermore, in the opinion of the committee, even a qualitative estimation of the corrodibility of the various materials in the various atmospheres based on only the weight change data would be of doubtful value at this time.

TABLE I.—LENGTH OF EXPOSURE PERIODS AT VARIOUS TEST LOCATIONS.

Location	9 by 12-in. Plate Specimens								Tension Specimens					
	First Period		Second Period		Third Period		Total Exposure Time		First Removal		Second Removal		Third Removal	
	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years
No. 1. Pittsburgh	428	1.17	622	1.71	984	2.70	2034	5.58	428	1.17	1154	3.16	2232	6.11
No. 2. Altoona, Pa.	438	1.20	607	1.66	973	2.67	2018	5.53	438	1.20	1148	3.14	2219	6.07
No. 3. State College	422	1.15	642	1.76	972	2.66	2036	5.57	422	1.15	1170	3.21	2217	6.07
No. 4. New York	456	1.25	627	1.72	972	2.66	2055	5.63	456	1.25	1205	3.30	2256	6.18
No. 5. Sandy Hook	470	1.29	626	1.72	988	2.71	2084	5.72	470	1.29	1198	3.28	2273	6.22
No. 6. Rochester	265	0.73	615	1.69	971	2.66	1851	5.08	420	1.15	1145	3.14	2215	6.06
No. 7. Key West, Fla.	416	1.14	632	1.73	988	2.71	2036	5.58	416	1.14	1145	3.14	2227	6.10
No. 8. Phoenix, Ariz.	389	1.06	623	1.71	942	2.58	1954	5.35	389	1.06	1111	3.04	2174	5.95
No. 9. La Jolla, Cal.	380	1.04	614	1.68	960	2.63	1954	5.35	380	1.04	1101	3.02	2164	5.92

For the purposes of comparison, the weight changes after 1-yr. and 3-yr. exposures, as previously reported in the 1933 and 1935 reports of Committee B-3,[1] have been included in the tables; also the orginal weights of the plate specimens before exposure, which will permit some rough estimate of the extent of corrosion at this time. These weight changes can be converted into the units in common use by reference to the tabulation of critical data and the table of densities published in the 1933 report of Committee B-3.[2]

However, where losses have occurred they are greatest in the industrial type of atmosphere and most marked in the case of nickel and zinc, whose corrosion products are not particularly protective in this type of atmosphere.

Tension Tests:

Tensile strength and percentage elongation were determined on the nine sets of corroded tension test specimens after approximately 6-yr. exposure to the atmosphere and on one set of uncorroded specimens stored in glass jars for the same period. These tests were made by the same industrial laboratories which had

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[1] *Loc. cit.*

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, pp. 235 and 237 (1933).

TABLE II.—SUMMARY OF CHANGES IN TENSILE PROPERTIES AFTER 1-YR., 3-YR., AND 6-YR. EXPOSURES.

Figures indicate percentage change (loss only) beyond the variation due to chance, those less than 1 per cent not given.

Material	Designation	Pittsburgh, Pa.						Altoona, Pa.						New York City						Rochester, N. Y.						Sandy Hook, N. J.					
		Tensile Strength			Elongation			Tensile Strength			Elongation			Tensile Strength			Elongation			Tensile Strength			Elongation			Tensile Strength			Elongation		
		1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.
Commercial Copper (Tough pitch)	A	...	2	4	...	2	...	...	2	5	...	...	...	...	1	3	...	...	...	...	...	2	...	...	...	...	...	2	...	...	...
Commercial copper (Phosphorized)	B	1	2	2	2	...	...	1	3	2	2	...	...	1	3	3	...	...	...	...	...	2	...	...	...	2	1	2	...	...	...
Copper-silicon-manganese alloy	C	...	1	3	...	...	...	...	2	3	...	...	...	...	1	...	...	...	...	...	...	2	...	...	...	...	1	3	...	...	...
Tin bronze	D	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Aluminum bronze	F	...	3	6	...	...	...	...	2	6	...	...	...	...	2	6	...	...	...	...	...	1	...	...	...	...	2	4	...	...	...
Manganese bronze	K	...	5	25	a	a	11[a]	3	9	20	a	a	62	...	13	32	a	a	32[a]	...	...	13	a	a	23[a]	...	...	18	a	a	45
Brass (85 Cu, 15 Zn)	L	...	2	6	...	...	...	...	1	5	...	...	...	...	1	4	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
Brass (70 Cu, 30 Zn)	M	2	8	11	...	...	6	...	6	15	...	2	13	4	10	16	...	5	10	...	...	1	...	...	...	1	2	5	...	...	3
Admiralty metal	N	...	3	5	...	...	...	...	7	4	...	...	...	...	2	5	...	...	...	...	...	2	...	...	...	...	1	3	...	...	...
Copper-nickel-zinc alloy	P	2	...	4	...	...	...	...	3	4	...	...	...	...	2	3	...	...	...	...	...	2	...	...	...	...	...	1	...	...	...
Copper-nickel-tin alloy	Q	...	...	...	a	a	a	...	...	...	a	a	a	...	...	...	a	a	a	...	...	...	a	a	a	...	...	...	a	...	a
Commercial aluminum	G	...	...	2	6	10	2	...	...	4	2	6	9	...	...	4	13	17	17	...	...	...	1	5	7	...	...	2	8	12	a
Aluminum-manganese alloy	I	1	3	4	7	a	6	2	4	6	5	...	...	...	4	2	23	5	3	...	...	...	...	...	...	...	2	...	...	a	...
Duralumin	O	2	5	4	17	26	19	3	7	6	28[a]	36	29	5	6	9	34	42	41	...	3	4	10	20	25	5	1	6	30	26	31
Aluminum-magnesium-silicon alloy	Z	1	4	7	12	12	28	...	6	10	14	27	34	3	5	8	28	29	35	...	...	4	4	14	31	2	3	7	20	27	35
Aluminum-coated duralumin	FF	...	...	...	...	...	4	...	...	...	...	...	4	...	...	...	...	...	...	...	...	...	...	...	a	...	...	...	...	...	...
Nickel-copper alloy	S	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Commercial nickel	T	...	2	5	...	...	...	...	4	7	...	...	...	...	2	6	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
Chemical lead	U	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	a	...	...	...	...	...	...
Lead-antimony alloy	CC	...	...	...	...	...	...	...	1	...	...	2	3	...	...	...	2	...	2	...	...	...	...	...	10	...	2	...	2	...	...
Commercial tin	EE	...	...	8	a	a	a	...	3	12	a	a	a	...	...	8	a	a	a	...	...	7	a	a	a	...	2	11	a	18[a]	19[a]
Commercial zinc (Prime Western grade)	AA	4	4	12	...	3	a	1	6	15	a	...	6[a]	2	5	13	4	a	a	...	...	5	2	12	4[a]	...	2	6	a	...	a
Commercial zinc (High grade)	BB	2	3	11	...	2	3	1	3	14	2	9	10	2	4	11	...	3	4	...	...	7	...	4	...	...	...	6	...	2	1
Commercial zinc (Special high grade)	HH	...	4	12	...	...	...	4	5	14	3	7	8	2	3	11	...	7	4	...	...	3	...	...	8	...	...	3	...	...	...

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[a] The "maximum percentage difference due to chance" value is 15 per cent or greater.

TABLE II.—(*Continued.*)

Material	Designation	Key West, Fla.						La Jolla, Calif.						State College, Pa.						Phoenix, Ariz.					
		Tensile Strength			Elongation			Tensile Strength			Elongation			Tensile Strength			Elongation			Tensile Strength			Elongation		
		1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.	1 yr.	3 yr.	6 yr.
Commercial Copper (Tough pitch)	A	...	...	...	...	...	...	...	1	5	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...
Commercial copper (Phosphorized)	B	...	...	...	...	...	...	...	2	5	...	...	3	...	...	...	2	...	...	...	...	...	1	...	...
Copper-silicon-manganese alloy	C	...	...	...	...	...	...	...	2	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Tin bronze	D	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Aluminum bronze	F	...	...	2	...	...	4	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...
Manganese bronze	K	...	...	12	[a]	[a]	5[a]	8	19	25	33[a]	34[a]	65[a]	...	...	...	[a]	[a]	[a]	...	...	...	[a]	[a]	[a]
Brass (85 Cu, 15 Zn)	L	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Brass (70 Cu, 30 Zn)	M	...	...	...	...	...	...	2	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Admiralty metal	N	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Copper-nickel-zinc alloy	P	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Copper-nickel-tin alloy	Q	...	...	...	...	[a]	[a]	...	...	...	[a]	[a]	[a]	...	...	...	[a]	[a]	[a]	...	...	...	[a]	[a]	[a]
Commercial aluminum	G	...	...	...	...	5	...	...	3	13	63	64	58	...	...	...	...	...	...	...	...	1	...	...	...
Aluminum-manganese alloy	I	...	...	...	...	[a]	...	...	4	4	28	47	42	...	...	...	...	...	...	...	...	...	...	[a]	[a]
Duralumin	O	1	2	...	23	24	23	30	29	33	81	82	86	...	...	...	...	...	...	...	...	...	...	...	...
Aluminum-magnesium-silicon alloy	Z	...	...	...	21	24	41	16	19	23	70	72	74	...	1	...	...	...	...	...	...	2	6	4	5
Aluminum-coated duralumin	FF	...	...	...	...	[a]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[a]	...
Nickel-copper alloy	S	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Commercial nickel	T	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	1
Chemical lead	U	...	...	...	2	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lead-antimony alloy	CC	...	2	...	3	2	...	...	1	...	...	1	4	...	...	...	...	...	...	...	4	2	2	...	...
Commercial tin	EE	...	...	11	[a]	[a]	[a]	...	3	15	26[a]	47	41[a]	...	...	6	[a]	[a]	[a]	...	...	11	[a]	[a]	[a]
Commercial zinc (Prime Western grade)	AA	...	...	2	[a]	...	[a]	7	6	19	51[a]	52	77[a]	...	1	5	[a]	...	[a]	...	...	2	[a]	...	[a]
Commercial zinc (High grade)	BB	...	...	4	...	...	...	4	5	11	1	31	32	...	...	3	...	...	...	...	...	3	...	...	...
Commercial zinc (Special high grade)	HH	...	...	...	...	1	3	2	6	8	6	31	32[a]	...	...	2	2	...	...	...	...	...	...	...	...

[a] The "maximum percentage difference due to chance" value is 15 per cent or greater.

made the earlier tests on the tension specimens after 1-yr. and 3-yr. exposures and, in general, the test procedure followed was identical with that used previously.

The percentage change in tensile properties was calculated and a statistical analysis of the results made in accordance with the procedure described in the 1935 report of Committee B-3.[1] The purpose of this statistical analysis is to determine what part of the change in tensile properties may be due to any one or all of the following chance factors:

1. Variations (non-uniformity) in the material comprising the set of six tension specimens at any one test location,
2. Variations in the amount of aging occurring in the specimens,
3. Variations in the testing machine itself and in the technique of the operator, and
4. Variations in the amount of corrosion suffered by the individual specimens making up a set of six at any location. (Not applicable to the "storage" specimens since these were kept in glass jars out of contact with atmosphere.)

The statistical evaluation of these variations is called the "maximum percentage difference due to chance" and, theoretically, any percentage *loss* in tensile strength or elongation greater than the "maximum percentage difference due to chance" value should be the net change due to corrosion. However, such a literal use of the data developed by statistical analyses methods cannot be made in all cases without some reservation, since there are apparently several instances where the data, for various reasons, cannot be considered as "homogeneous" (produced under controlled conditions).

The complete data from the tension tests on specimens exposed for 6 yr. are given in the tabulations included with this report. In some instances the data represent tests of less than six specimens because of loss, mechanical damage, or failure to break within the gage limits, and appropriate notations in the tabulations call attention to such cases. Space limitations do not permit including similar data from tension tests made on the 1-yr. and 3-yr. specimens, which appears in complete form in previous reports of Committee B-3.[2]

The net percentage change in tensile properties, that is, the amount of change in excess of the "maximum percentage difference due to chance," has been determined for all cases where these changes appear as *losses* and a summary of the results for the 1, 3, and 6-yr. exposure periods appears in Table II. However, only those net losses greater than 1 per cent are included in this tabulation. A notation has also been inserted in the tables wherever the "maximum percentage difference due to chance" figure is 15 per cent or greater, to call attention to materials in which for various reasons wide variations in the mechanical properties are to be expected. In some instances differences in the amount of corrosion experienced by the individual specimens may have been contributory factors in enlarging the "maximum percentage difference due to chance" value.

In view of the small losses of tensile properties experienced by many of the metals and alloys, it is still too early to attempt rating them on the basis of their corrosion resistance or to predict their probable life in any atmosphere. To what extent losses in tensile properties present an accurate picture of the corrosion resistance of these metals when used in the atmosphere depends upon the character of the service conditions for which the materials are being considered, also on the form and thickness in which they are to be used. Nevertheless, a few interesting observations can be made at this time to advantage.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 144 (1935).

[2] *Loc. cit.*

The tension test results summarized in Table II show clearly that substantial losses in tensile strength or percentage elongation, or both, have occurred at most of the industrial and sea coast locations for the three samples of zinc, materials AA, BB and HH; commercial aluminum, material G; the aluminum alloys, materials I, O, and Z; manganese bronze (high-tensile-strength yellow brass), material K; 70–30 brass, material M; and tin, material E.

With the exception of the 70–30 brass and manganese bronze (high-tensile-strength yellow brass), the losses of tensile properties of the coppers and other copper alloys at all test locations are so small as to be of little significance at this time. The same is true for nickel and the high nickel-copper alloys as well as lead and the lead-antimony alloy.

In the rural locations the losses of tensile properties are negligible for all materials except tin.

Loss in tensile properties has apparently had no relation to change in weight on uncleaned specimens irrespective of the type of atmosphere, the character of the corrosive attack, or the kind of metal or alloy. This is to be expected in the case of those metals subject to serious pitting, or an intercrystalline type of corrosion, or alloys susceptible to dezincification, or where corrosion products are particularly adherent.

Visual Inspection of Corroded Specimens:

The 9 by 12-in. plate specimens were inspected at the National Bureau of Standards at a meeting of the subcommittee on November 11, 1937. The appearance of the various materials at each test location after 6-yr. exposure is briefly described under "Remarks" in the accompanying tabulations.

In general, the terms "tarnish," "film," and "scale" have been used in these descriptions in much the same manner as in previous inspections. However, the meaning of these terms has been amplified somewhat as follows:

> *Tarnish* is a superficial layer of corrosion products of insufficient thickness to hide or obliterate the usual roll marks or handling scratches discernible in the surface of the unexposed metal.
>
> *Film* is a layer of corrosion products substantially adherent in character and of sufficient thickness completely to cover up roll marks or other light surface markings in the original surface of the metal.
>
> *Scale* is a very heavy, generally rough, more or less loosely adherent layer of corrosion products which usually can be easily dislodged from the surface of the metal by any slight mechanical deformation.

The brownish color of the corrosion products on the zinc specimens, materials AA, BB and HH, at the Pittsburgh location is doubtless due to their immersion in muddy water at the time of the Ohio River flood. This brownish discoloration is probably the result of the inclusion of fine particles of silt or mud in the corrosion product films and doubtless some of these particles were retained in the film in spite of the washing and cleaning treatment to which these samples were subjected after the flood subsided. The deposits of a brownish colored powder noticed on some of the zinc and lead specimens at Phoenix, Ariz., also is probably the result of some accidental contact with muddy ground water or may have resulted from dust deposited on the contact surfaces of specimens which had come in contact with each other through accidental deformation in their frames on the racks. In both cases these discolorations of the corrosion products should be considered as abnormal for these localities and due consideration should be given to the foregoing in evaluating the significance of the weight changes on these particular specimens.

TABLE III.—SUMMARY OF METEOROLOGICAL DATA AT TEST LOCATIONS.

Station		No. 1 Pittsburgh, Pa.	No. 2 Altoona, Pa.	No. 4 New York City	No. 6 Rochester, N. Y.	No. 5 Sandy Hook, N. J.	No. 7 Key West, Fla.	No. 9 La Jolla, Calif.	No. 3 State College, Pa.	No. 8 Phoenix, Ariz.
Type of Exposure		Industrial	Industrial	Industrial	Industrial	Sea Coast	Sea Coast	Sea Coast	Rural	Rural
Elevation, ft.		842	1615	150	523	22	22	50	1217	1108
Temperature, Mean Annual, Deg. Fahr.	1931	55	....	55	51	55	76	64	52	72
	1932	53.5	50	54	49	54	78	61	50	71
	1933	53.6	50	54	50	....	78	60	51	71
	1934	52.7	....	52.2	47.9	52	77.5	63.3	49.7	74
	1935	52.1	....	52.6	47.8	52.4	77.2	61.5	49.1	71
	1936	51.0	48.6	52.9	48.2	53	77.4	62.8	49.0	73
	1937	50.9	48.7	53.9	48.8	53.9	77.4	61.5	49.3	71
Precipitation, Yearly Total, in.	1931	39	....	35	31	32	51	15	34	10
	1932	25.9	38	39	40	36	40	11	38	7
	1933	40.3	51	50	26	....	52	8	44	7
	1934	31.67	36.41	44.96	24.46	41.00	31.50	8.87	35.54	5.87
	1935	34.44	37.71	32.64	29.65	32.16	39.62	10.20	37.41	10.33
	1936	38.47	47.31	46.33	30.08	42.68	50.46	14.42	47.12	8.29
	1937	37.66	49.20	48.1	33.03	41.47	49.3	10.09	45.67	5.37
Snowfall, in.	1931	16	....	7	63	4	0	0	24	0
	1932	19.5	44	13	79	12	0	0	30	0
	1933	20.6	31	28	57	....	0	0	28	0
	1934	24.2	....	38.8	55.5	29.9	0	0	22.6	0
	1935	41.8	55.6	39.0	63.2	34.1	0	0	53.2	0
	1936	53.3	64.0	25.3	82.8	9.2	0	0	65.4	0
	1937	23.1	34.0	11.3	58.50	8.4	0	0	31.9	0
Number of Days Precipitation (rain or snow), 0.01 in. or over..	1931	176	....	151	154	116	119	48	113	38
	1932	133	129	116	168	121	119	40	117	37
	1933	140	156	129	160	....	105	40	149	37
	1934	125	....	122	161	129	124	38	117	26
	1935	159	131	120	168	131	100	43	139	47
	1936	142	126	139	165	127	132	54	124	39
	1937	155	130	137	162	128	124	54	140	32
Relative Humidity, per cent.	1931	73	....	66	70	73	77	75	....	38
	1932	66	....	63	68	71	74	74	....	34
	1933	68	....	67	66	....	76	75	....	34
	1934	69	....	65	66	73	75	77	....	32
	1935	74	....	66	69	76	73	75	....	38
	1936	71	....	66	68	74	76	75	....	34
	1937	69	....	63	66	75	76	75	....	36
Sunshine, Percentage of Possible..	1931	54	....	62	50	55	66	67	....	84
	1932	58	....	62	48	58	70	65	....	84
	1933	50	....	57	46	....	70	67	....	84
	1934	56	....	60	47	54	71	71	....	85
	1935	50	....	56	47	58	74	62	....	75
	1936	62	....	63	48	62	69	75	....	84
	1937	52	....	59	48	58	67	67	....	84
Wind, Average Hourly Velocity, m.p.h., and Prevailing Direction	1931	8.7 W.	....	13.4 N.W.	8.7 W.	12.7 W.	9.1 E.	6.6 W.	....	6.0 E.
	1932	10.0 W.	.... W.	15.1 N.W.	9.2 W.	14.6 W.	9.7 E.	6.5 W.	.... W.	6.1 E.
	1933	10.05 W.	.... W.	14.2 N.W.	8.8 W.	......	9.9 E.	6.4 N.W.	.... W.	6.0 E.
	1934	9.5 S.W.	.... W.	13.8 N.	8.1 S.W.	13.6 S.W.	9.4 E.	6.4 W.	.... W.	5.9 E.
	1935	9.8 S.W.	.... W.	14.2 N.	8.4 S.W.	13.9 S.W.	9.6 E.	6.3 N.W.	.... W.	5.7 E.
	1936	10.6 S.W.	.... W.	14.5 N.W.	9.0 S.W.	14.1 W.	9.9 E.	6.7 N.W.	.... W.	5.8 E.
	19 7	10.7 N.W.	.... W.	14.0 N.W.	9.3S.W.-W.	13.9 W.	9.7 E.	6.5 N.W.	.... W.	5.9 E.

Test Atmospheres:

A summary of the meteorological data from the nine test locations, as taken from the regular Government Weather Bureau reports, is given in Table III. Unfortunately, however, the corrosiveness of the atmosphere at these locations, as indicated by the loss of weight and tension test data, appears to bear no correlation to the usual weather phenomena reported for the test areas. For instance, information is entirely lacking on the degree to which atmospheres classified as "industrial" are contaminated by corrosive gases resulting from combustion of fuel and other industrial processes. Likewise, there is no knowledge of the frequency with which the surfaces of the specimens are wet by such atmospheric phenomena as light rains, fogs, dew falls or frost formation, nor is there available any information on how long the surfaces of the specimens remain in a moist condition. Factors of this sort are probably of greater importance in determining the corrosiveness of a given atmosphere than total rainfall, or percentage sunshine, or percentage relative humidity.

The general classification of the test location atmospheres as "industrial," "sea coast," and "rural" cannot be taken too literally. For example, quite a difference is noticeable between the corrosiveness of the New York City and Rochester, N. Y., atmospheres, both of which are classified as "industrial." This is only to be expected when the comparative size of the industrial areas at each of these locations is considered and allowance is made for degrees of industrial activity in these areas over the period of time covered by the exposure tests. Furthermore, Sandy Hook, N. J., classified as "sea coast," is not truly typical of northern sea coast exposures since undoubtedly its close proximity to the New York City area results in some contamination of its atmosphere by industrial gases.

The test data do indicate, however, that New York City is still the most corrosive of the industrial atmospheres and La Jolla, Calif., the most corrosive of the sea coast locations.

Respectfully submitted on behalf of the subcommittee,

W. H. FINKELDEY,
Chairman

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material A—Commercial Copper (Tough Pitch) (99.9+ Cu, 0.026 O)									
Pittsburgh No. 1	530.85 526.79	+1.44 +1.42	+0.07 −0.07	−2.34 −2.48	32 200	43.6	−4.2 (*0.7*)	−1.4 (*4.2*)	Irregular green and black adherent rough scale with dirt and soot.
Altoona No. 2	528.08 532.16	+0.26 +0.29	−0.93 −1.04	−3.02 −2.95	31 900	44.5	−5.1 (*0.5*)	+0.7 (*2.6*)	Uniform brownish-black adherent light scale with considerable dirt and soot.
New York City No. 4	560.96 557.28	−0.83 −0.83	−2.77 −2.81	−5.42 −5.52	32 400	43.5	−3.6 (*0.8*)	−1.6 (*2.4*)	Spotty dark green adherent light rough scale with red-brown areas.
Rochester No. 6	539.54 532.08	+0.30 +0.28	+1.54 +1.49	+2.83 +2.60	32 700	44.3	−2.7 (*0.7*)	+0.2 (*2.2*)	Mottled, "peacock" colored adherent rough scale.
Sandy Hook No. 5	562.78 560.59	+0.49 +0.59	+0.43 +0.56	+0.19 +0.20	32 800	43.5	−2.4 (*0.6*)	−1.6 (*2.5*)	Olive-green over red-brown, adherent fairly smooth scale with spots of patina green.
Key West No. 7	559.49 559.08	+0.42 +0.43	+0.56 +0.59	+0.72 +0.76	33 600	44.3	0.0 (*1.6*)	+0.2 (*2.9*)	Red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9	528.87 531.87	+1.54 +1.48	+1.89 +1.78	+2.38 +2.20	31 700	43.4	−5.7 (*1.0*)	−1.8 (*6.3*)	Red-brown film with overlying blue-green friable scale, heaviest at edges.
State College No. 3	560.33 560.99	+0.33 +0.33	+0.57 +0.56	+0.81 +0.80	32 800	43.7	−2.4 (*0.6*)	−1.1 (*3.1*)	Dark olive-green adherent smooth film.
Phoenix No. 8	561.29 556.44	+0.12 +0.14	+0.10 +0.13	+0.18 +0.21	33 300	43.9	−0.9 (*1.1*)	−0.7 (*3.2*)	Mottled red-brown adherent smooth film with large green-black central area.
Material B—Commercial Copper (Phosphorized) (99.9+ Cu, 0.007 P)									
Pittsburgh No. 1	558.66 559.92	+1.27 +1.15	−0.09 −0.21	−2.35 −2.35	34 500	41.0	−3.1 (*0.8*)	−3.5 (*3.6*)	Irregular green and black adherent rough scale with some dirt and soot.
Altoona No. 2	553.42 552.29	+0.06 +0.04	−1.17 −1.16	−3.07 −3.00	34 400	41.0	−3.0 (*1.1*)	−3.5 (*3.5*)	Uniform brownish-black adherent light scale with considerable dirt and soot.
New York City No. 4	554.57 554.15	−0.84 −0.85	−2.71 −2.72	−5.25 −5.28	34 000	41.0	−4.2 (*1.0*)	−3.5 (*2.9*)	Mottled green over red-brown film.
Rochester No. 6	557.40 559.36	+0.27 +0.27	+1.40 +1.37	+2.24 +2.24	34 600	41.5	−2.5 (*0.8*)	−2.4 (*2.7*)	Mottled "peacock" colored adherent rough scale.
Sandy Hook No. 5	552.71 551.59	+0.51 +0.49	+0.39 +0.36	0.00 −0.03	34 400	42.0	−3.0 (*1.2*)	−1.2 (*2.8*)	Olive-green adherent light smooth scale with greenish white spots.
Key West No. 7	559.50 554.67	+0.38 +0.38	+0.53 +0.53	+0.74 +0.75	35 000	43.0	−1.4 (*1.3*)	+1.2 (*2.8*)	Red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9	554.90 553.67	+1.32 +1.40	+1.58 +1.65	+1.87 +1.94	33 600	40.0	−5.4 (*0.9*)	−5.8 (*3.2*)	Red-brown film with overlying blue-green friable scale heaviest at edges.
State College No. 3	549.68 553.64	+0.32 +0.32	+0.54 +0.54	+0.75 +0.74	35 000	42.0	−1.4 (*0.8*)	−1.2 (*4.1*)	Uniform dark olive-green adherent smooth film.
Phoenix No. 8	555.28 554.57	+0.11 +0.13	−0.09 +0.10	+0.18 +0.19	35 700	41.0	+0.6 (*0.8*)	−3.5 (*2.9*)	Mottled red-brown adherent smooth film.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material A				
Original	35 200	42.4		
After 6 yr.	33 600	44.2	−4.6 (*1.7*)	+4.3 (*2.5*)
Material B				
Original	35 150	38.7		
After 6 yr.	35 500	42.5	+1.0 (*0.9*)	+9.8 (*2.9*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material C—Copper-Silicon-Manganese Alloy (96 Cu, 3 Si, 1 Mn)									
Pittsburgh No. 1	543.63 538.80	+1.42 +1.16	+0.68 +0.47	−0.88 −1.07	56 200	57.9	−5.5 (*2.3*)	−1.9 (*3.3*)	Mottled gray-black scale with gray-green areas, some dirt and soot.
Altoona No. 2	538.17 537.16	+0.18 −0.15	−0.63 −1.09	−2.43 −2.88	53 200	59.4	−10.6 (*7.5*)	+0.7 (*3.0*)	Mottled gray-black adherent rough scale, considerable dirt and soot.
New York City No. 4	534.56 536.72	−0.89 −0.88	−2.63 −2.65	−5.81 −5.78	56 500	58.6	−5.1 (*4.7*)	−0.7 (*4.7*)	Mottled grayish-green scale.
Rochester No. 6	525.96 543.12	+0.27 +0.26	+1.33 +1.25	+2.40 +2.09	57 200	59.7	−3.9 (*1.9*)	+1.2 (*2.8*)	Mottled "peacock" colored adherent rough scale.
Sandy Hook No. 5	534.64 534.88	+0.47 +0.49	+0.75 +0.78	+0.32 +0.53	56 300	59.3	−5.4 (*2.5*)	+0.5 (*2.5*)	Brownish-green scale with large green-white areas on upper part.
Key West No. 7	539.43 540.13	+0.44 +0.42	+0.84 +0.78	+1.35 +1.28	57 800	59.0	−2.9 (*2.0*)	0. (*2.7*)	Red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9	543.38 543.23	+1.92 +1.77	+3.06 +2.92	+4.37 +4.33	55 800	59.4	−6.2 (*2.6*)	+0.7 (*2.6*)	Red-brown film with overlying blue-green friable scale heaviest at edges.
State College No. 3	545.71 534.63	+0.11 −0.05	+0.16 −0.10	+0.11 −0.13	58 400	58.3	−1.9 (*1.9*)	−1.2 (*3.1*)	Yellow-brown streaks and large olive-green areas of heavy film.
Phoenix No. 8	542.32 537.15	+0.12 +0.16	+0.09 +0.10	+0.18 +0.20	59 000	58.7	−0.8 (*2.2*)	−0.5 (*2.8*)	One side: yellow-brown adherent smooth tarnish, blackened near ends; other side: uniform greenish-brown heavy film.
Material D—Tin Bronze (92 Cu, 8 Sn)									
Pittsburgh No. 1	541.68 541.63	+2.23 +2.26	+2.90 +2.51	−0.14 −0.53	55 400	65.2	−2.5 (*1.3*)	−0.5 (*2.7*)	Mottled grayish-green adherent rough scale with considerable dirt and soot.
Altoona No. 2	551.10 551.29	+0.79 +0.83	−0.67 −0.57	−4.44 −4.63	55 200	65.7	−2.8 (*2.6*)	+0.3 (*2.3*)	Uniform brown-black adherent rough scale with considerable dirt and soot.
New York City No. 4	554.93 549.98	−0.22 −0.19	−2.57 −2.08	−7.71 −7.12	55 400	65.5	−2.5 (*2.8*)	0. (*3.5*)	Grayish-green adherent film with dark olive-green areas.
Rochester No. 6	540.68 542.83	+0.31 +0.30	+1.61 +1.51	+4.06 +3.98	57 500	65.8	+1.2 (*2.5*)	+0.5 (*2.5*)	Mottled "peacock" colored adherent rough scale.
Sandy Hook No. 5	529.86 537.02	+0.63 +0.65	+0.83 +0.86	+0.95 +0.81	56 700	66.0	−0.2 (*1.3*)	+0.8 (*3.2*)	Olive-green adherent smooth film with band of light green scale at top.
Key West No. 7	547.13 536.40	+0.52 +0.53	+0.89 +0.89	+1.17 +1.12	57 300	66.0	+0.9 (*1.6*)	+0.8 (*2.6*)	Red-brown adherent smooth film with scale at edges.
La Jolla No. 9	543.77 547.70	+1.83 +1.71	+2.37 +2.13	+2.08 +1.70	54 800	65.8	−3.5 (*2.0*)	+0.5 (*2.5*)	Red-brown non-adherent scale with non-uniform non-adherent green over-layer.
State College No. 3	529.64 534.33	+0.11 +0.14	+0.25 +0.31	+0.27 +0.36	57 000	65.0	+0.4 (*2.0*)	−0.8 (*2.6*)	Mottled greenish-brown adherent light smooth film.
Phoenix No. 8	551.11 533.77	+0.14 +0.12	+0.11 +0.10	+0.22 +0.21	58 200	66.2	+2.5 (*2.6*)	+1.1 (*2.2*)	Mottled and streaked orange-brown adherent film.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material C				
Original After 6 yr.	59 050 59 500	55.7 59.0	+0.8 (*2.1*)	+5.9 (*2.6*)
Material D				
Original After 6 yr.	58 925 56 800	66.2 65.5	−3.6 (*2.0*)	−0.9 (*1.7*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material F—Aluminum Bronze (92 Cu, 8 Al)									
Pittsburgh No. 1	490.85 479.69	+1.57 +1.60	+2.43 +2.28	−0.09 −0.53	70 900	48.8	−8.4 (*2.6*)	+3.8 (*1.7*)	Uniform black adherent rough film with gray underfilm showing through in spots with some dirt and soot.
Altoona No. 2	501.76 515.14	+0.34 +0.47	+0.59 +0.86	+0.56 +0.85	71 400	48.8	−7.7 (*1.4*)	+3.8 (*1.7*)	Uniform black adherent rough film with considerable dirt and soot.
New York City No. 4	496.21 506.66	−0.03 −0.01	−0.55 −0.47	−1.09 −0.97	71 700	48.6	−7.4 (*1.8*)	+3.4 (*1.5*)	Mottled "peacock" colored adherent rough scale.
Rochester No. 6	498.64 492.98	+0.18 +0.20	+1.44 +1.50	+4.44 +4.58	74 300	46.3	−4.0 (*2.8*)	−1.5 (*1.8*)	Streaky greenish-black adherent rough scale.
Sandy Hook No. 5	491.98 495.54	+0.31 +0.31	+0.59 +0.59	+1.47 +1.46	73 100	48.0	−5.6 (*1.4*)	+2.1 (*2.2*)	Dirty brown adherent rough scale.
Key West No. 7	482.78 490.84	+0.26 +0.07	+0.39 +0.41	+0.55 +0.59	75 100	44.2	−3.0 (*1.3*)	−6.0 (*1.7*)	Light red-brown adherent smooth film, green at edges.
La Jolla No. 9	493.12 493.38	+0.93 +0.95	+0.93 +0.92	+0.43 +0.40	84 500	36.3	+0.7 (*7.4*)	−7.4 (*8.2*)	Pea green adherent friable scale with yellow under-film showing at edges.
State College No. 3	493.94 506.41	−0.03 −0.03	−0.12 −0.13	−0.22 −0.24	74 400	49.1	−3.9 (*1.6*)	+4.5 (*1.4*)	Uniform yellow-bronze tarnish.
Phoenix No. 8	498.31 502.84	+0.09 +0.08	+0.04 +0.04	+0.07 +0.08	82 400	40.6	−1.8 (*2.1*)	+3.6 (*4.7*)	Uniform golden yellow tarnish with considerable dirt on one side.
Material G—Commercial Aluminum (99+ Al)									
Pittsburgh No. 1	167.49 167.00	+0.25 +0.23	+0.35 +0.32	+0.71 +0.54	16 030	11.0	−3.8 (*1.6*)	−10.6 (*8.5*)	Samples show some mechanical damage. Surface generally dirty and roughened with very fine pattern of hard adherent scale.
Altoona No. 2	166.78 167.86	+0.31 +0.27	+0.68 +0.53	+1.12 +0.93	15 870	9.8	−4.9 (*1.0*)	−20.3 (*11.7*)	Samples show some mechanical damage. Surface generally dark, dirty and roughened with very fine pattern of hard adherent scale
New York City No. 4	166.28 166.40	+0.39 +0.36	+0.55 +0.50	+0.88 +0.82	15 930	9.3	−4.6 (*0.7*)	−24.4 (*7.8*)	Surface dirty and generally roughened with very fine pattern of hard adherent scale.
Rochester [c] No. 6	169.29 169.02	+0.09 +0.10	+0.25 +0.26	+0.50 +0.48	16 520	10.3	−1.1 (*2.6*)	−16.3 (*9.0*)	Dull dirty film speckled with small spots of darker hard adherent scale.
Sandy Hook No. 5	166.81 168.29	+0.28 +0.26	+0.59 +0.50	+0.59 +0.48	16 225	10.3	−2.8 (*1.6*)	−16.3 (16.8)	Dull dirty film speckled with fine spots of darker hard adherent scale, more severe attack at edges.
Key West [d] No. 7	166.87 169.48	+0.09 +0.14	+0.32 +0.25	+0.54 +0.47	16 355	12.4	−2.0 (*1.6*)	+0.8 (*12.2*)	About 50 per cent of surface shows metallic luster; remainder, gray thin film with light scale spots, heavier scale near edges.
La Jolla No. 9	168.12 170.14	+0.76 +0.76	+1.42 +1.40	+2.58 +2.51	13 505	4.4	−19.1 (*5.8*)	−64.2 (*6.3*)	Dull gray thin scale with uniformly distributed mounds of heavier granular scale, 20 per cent of remaining area shows metallic luster.
State College No. 3	166.24 166.78	0.00 +0.01	−0.01 0.00	−0.01 −0.01	16 565	12.5	−0.8 (*2.7*)	+1.6 (*9.0*)	Generally discolored but still showing metallic luster, uniformly distributed small light-gray spots over the mottled tarnished background.
Phoenix No. 8	168.03 169.05	+0.04 +0.04	+0.01 +0.01	+0.04 +0.03	16 630	12.8	−2.2 (*1.4*)	+4.1 (*10.7*)	General metallic luster over entire surface with

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material F				
Original	(1)74 070 (2)82 858	46.6 39.9		
After 6 yr.	(1)77 400 (2)83 900	47.0 39.2	+4.3 (*1.8*) +1.3 (*1.7*)	+0.9 (*5.2*) −1.8 (*4.0*)
Material G				
Original	16 410	14.6		
After 6 yr.	16 695	12.3	+1.7 (*0.5*)	−15.8 (*16.6*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] Two lots of material F, necessitating tests of two storage sets:

(1) Value for use with results from stations No. 1 to No. 7, inclusive.

(2) Values for use with results from stations No. 8 and No. 9.

[c] Specimen 6G1 was damaged mechanically.

[d] Specimen 7G1 was damaged mechanically.

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material I—Aluminum-Manganese Alloy (1 per cent Mn)									
Pittsburgh No. 1.....	169.23 168.17	+0.21 +0.21	+0.09 +0.09	+0.11 +0.21	19 460	7.2	−4.9 (*1.2*)	−18.2 (*11.9*)	Surface generally dirty, roughened with irregular white spotted areas suggesting splashes.
Altoona No. 2.....	166.41 167.31	+0.25 +0.23	+0.26 +0.02	+0.01 −0.25	19 030	7.8	−6.9 (*0.7*)	−11.4 (*13.3*)	Surface dark and dirty, roughened with irregular white spotted areas suggesting splashes.
New York City No. 4.....	166.80 167.83	+0.22 +0.24	+0.21 +0.21	+0.22 +0.22	19 595	7.3	−4.1 (*1.9*)	−17.1 (*14.3*)	Surface dirty and generally roughened with very fine pattern of hard adherent scale.
Rochester No. 6.....	170.47 171.00	+0.13 +0.14	+0.25 +0.26	+0.33 +0.34	20 290	9.4	−0.7 (*1.1*)	+6.8 (*12.6*)	Both specimens considerably damaged, somewhat less severe surface attack than Material G, although generally similar in appearance.
Sandy Hook No. 5.....	167.51 166.29	+0.16 +0.24	+0.25 +0.37	+0.18 +0.30	20 095	8.2	−1.7 (*1.3*)	−6.8 (*12.3*)	Dull dirty film speckled with fine spots of darker hard adherent scale; more severe attack at edges.
Key West No. 7.....	167.63 168.93	+0.08 +0.09	+0.15 +0.20	+0.28 +0.34	20 360	9.6	−0.4 (*0.7*)	+9.1 (*12.3*)	About 50 per cent of surface shows metallic luster; remainder, gray thin film with light scale spots, heavier scale near edges.
La Jolla No. 9.....	166.49 166.09	+0.58 +0.56	+0.85 +0.78	+1.56 +1.45	19 200	4.1	−6.1 (*2.1*)	−53.4 (*11.9*)	Dull gray thin scale with uniformly distributed mounds of heavier granular scale; 20 per cent remaining area still show metallic luster. Attack not severe as in Material G.
State College No. 3.....	166.83 168.27	+0.10 0.00	+0.08 −0.01	+0.06 −0.04	20 280	9.4	−0.8 (*0.7*)	+6.8 (*13.6*)	Generally discolored but still showing metallic luster, uniformly distributed small light-gray spots over the mottled tarnished background.
Phoenix No. 8.....	167.20 166.87	+0.03 +0.03	+0.01 +0.01	+0.03 +0.04	20 040	8.9	−1.9 (*1.7*)	+1.1 (*23.2*)	General metallic luster over entire surface with a mottled pattern of gray spots; fine black spots uniformly distributed on numbered side.
Material K—Manganese Bronze (High-Tensile-Strength Yellow Brass) (66.4 Cu, 19.3 Zn, 5.88 Al, 4.6 Fe ,3.78 Mn)									
Pittsburgh No. 1.....	411.92 474.27	+1.24 +1.29	+2.59 +2.64	+3.35 +1.98	86 930	4.4	−29.6 (*4.2*)	−35.2 (*24.5*)	Uniform blue-black friable scale stippled[b] with gray spots.
Altoona No. 2.....	442.70 432.72	+1.16 +1.09	+2.47 +2.31	+4.40 +4.25	86 550	2.3	−30.0 (*10.1*)	−67.7 (*5.7*)	Uniform black adherent rough scale stippled[b] with gray spots.
New York City No. 4.....	477.86 489.40	+1.14 +1.12	+1.97 +1.95	+3.16 +3.08	78 440	3.4	−36.4 (*4.9*)	−52.2 (*19.9*)	Uniform black adherent rough scale, stippled[b] with gray spots.
Rochester No. 6.....	459.04 454.23	+0.46 +0.43	+1.88 +1.75	+4.22 +4.19	102 533	2.3	−17.0 (*4.3*)	−67.7 (*45.2*)	Stippled[b] black adherent rough scale.
Sandy Hook No. 5.....	433.18 499.31	+0.85 +0.73	+1.68 +1.40	+2.85 +2.44	95 020	3.4	−23.1 (*4.9*)	−52.2 (*6.8*)	Uniform brownish-black adherent rough scale slightly stippled[b] with gray spots.
Key West No. 7.....	503.91 493.35	+0.56 +0.56	+1.74 +1.68	+3.15 +2.87	103 820	5.0	−16.0 (*3.7*)	−29.6 (*24.2*)	Uniform dark brown adherent rough scale stippled[b] with black spots.
La Jolla No. 9.....	488.56 465.51	+1.50 +1.65	+2.50 +2.85	+3.90 +5.11	84 370	0.9	−31.7 (*6.5*)	−87.3 (*22.0*)	Black adherent rough scale stippled[b] with gray spots.
State College No. 3.....	449.61 460.53	−0.05 −0.02	−0.17 −0.11	−0.33 −0.24	118 600	6.9	−4.0 (*6.0*)	−2.8 (*22.0*)	Greenish-brown adherent smooth film with scattered dark spots.
Phoenix No. 8.....	463.03 477.77	+0.09 +0.10	+0.07 +0.07	+0.15 +0.16	117 270	5.8	−5.1 (*6.0*)	−18.3 (*46.4*)	Uniform brown tarnish with some black streaks.

CHANGES DUE TO AGING
(STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material I				
Original....... After 6 yr.....	20 450 20 435	9.4 8.8	−0.1 (*1.2*)	−6.4 (*4.5*)
Material K				
Original....... After 6 yr.....	122 000 123 560	8.5 7.1	+1.3 (*5.4*)	−16.5 (*39.2*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] Stippling probably indicates dezincification.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material L—Brass (85 Cu, 15 Zn)									
Pittsburgh No. 1.....	544.98 545.76	+1.36 +1.21	+1.18 +1.19	−0.37 −0.39	37 600	40.6	−8.1 (*2.7*)	0.0 (*3.9*)	Fairly uniform black adherent rough scale.
Altoona No. 2.....	546.77 546.45	+0.78 +0.72	+0.54 +0.46	+0.48 −0.99	38 000	41.4	−7.1 (*2.3*)	+0.2 (*4.4*)	Uniform bluish-black adherent rough scale with considerable dirt and soot.
New York City No. 4.....	546.73 546.75	−0.07 −0.12	−1.79 −1.72	−6.01 −5.60	38 200	40.6	−6.6 (*2.6*)	0.0 (*3.8*)	Blue-black adherent rough scale with slate-gray areas.
Rochester No. 6.......	546.28 545.76	+0.24 +0.27	+1.38 +1.20	+3.46 +3.25	39 700	40.0	−2.9 (*2.3*)	−1.5 (*3.5*)	Mottled "peacock" colored adherent rough scale.
Sandy Hook No. 5.....	548.18 549.19	+0.37 +0.37	+0.24 +0.23	+0.05 +0.04	39 700	41.0	−2.9 (*2.2*)	+1.0 (*2.8*)	Uniform olive-green adherent light smooth scale.
Key West No. 7.....	547.89 547.47	+0.24 +0.22	+0.27 +0.25	+0.27 +0.25	40 600	40.0	−0.7 (*2.3*)	−1.5 (*4.3*)	Uniform red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9.....	546.90 544.94	+1.15 +1.08	+1.39 +1.31	+1.58 +1.52	40 100	41.0	−2.0 (*2.3*)	+1.0 (*4.1*)	Red-brown adherent film with large areas of blue-green adherent scale.
State College No. 3.....	546.82 547.40	+0.01 +0.01	−0.12 −0.01	−0.42 −0.39	40 400	40.6	−1.2 (*2.4*)	0.0 (*4.8*)	Dark brown adherent film.
Phoenix No. 8.....	543.16 543.81	+0.10 +0.10	+0.07 +0.07	+0.13 +0.11	41 200	41.0	+0.7 (*2.4*)	+1.0 (*2.9*)	Mottled yellow-brown adherent smooth film.
Material M—Brass (70 Cu, 30 Zn)									
Pittsburgh No. 1.....	535.30 549.14	−0.45 −0.47	−1.86 −2.71	−6.02 −5.99	41 800	52.5	−13.5 (*2.4*)	−11.8 (*6.1*)	Irregular bluish-black adherent scale.
Altoona No. 2.....	534.26 562.14	−0.53 −0.50	−2.27 −2.33	−4.95 −4.95	40 100	48.0	−17.0 (*1.9*)	−19.3 (*6.7*)	Uniform bluish-black adherent rough scale with considerable dirt and soot.
New York City No. 4.....	562.49 559.08	−1.42 −1.47	−4.15 −4.29	−7.80 −7.80	39 700	49.5	−17.8 (*2.2*)	−16.8 (*7.1*)	Mottled bluish-brown adherent light scale.
Rochester No. 6.....	535.53 534.82	+0.20 +0.19	+0.52 +0.49	+1.36 +1.35	46 700	59.0	−3.3 (*2.2*)	−0.8 (*8.4*)	Dark "peacock" colored adherent rough scale,
Sandy Hook No. 5.....	534.17 558.64	+0.21 +0.23	−0.06 −0.10	−0.45 −0.53	44 800	54.0	−7.2 (*2.3*)	−9.2 (*6.4*)	Uniform dark greenish-blue adherent light scale.
Key West No. 7.....	555.26 532.56	−0.14 +0.16	−0.25 +0.06	−0.38 −0.08	47 800	59.0	−1.0 (*2.5*)	−0.8 (*6.7*)	Dusty green-gray adherent outer film over red-brown adherent smooth film.
La Jolla No. 9.....	558.86 534.68	+0.82 +0.89	+0.85 +0.88	+0.82 +0.82	46 400	58.0	−4.0 (*2.0*)	−2.5 (*5.7*)	Mottled grayish-green adherent light scale with dark green areas.
State College No. 3.....	553.82 558.59	−0.05 −0.06	−0.23 −0.24	−0.51 −0.53	47 500	59.5	−1.7 (*2.1*)	0.0 (*5.7*)	Olive green adherent smooth film.
Phoenix No. 8	555.43 534.02	+0.12 +0.10	+0.07 +0.06	+0.08 +0.07	48 400	58.0	+0.2 (*2.5*)	−2.5 (*6.9*)	Dark brown adherent smooth film.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material L				
Original.......	39 896	40.7		
After 6 yr.....	40 900	40.6	+2.5 (*2.2*)	−0.3 (*0.9*)
Material M				
Original.......	48 033	52.3		
After 6 yr.....	48 300	59.5	+0.6 (*1.9*)	+13.8 (*4.8*

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material N—Admiralty Metal (70 Cu, 29 Zn, 1 Sn)									
Pittsburgh No. 1.....	533.72 533.85	+0.69 +0.74	+0.60 −0.28	−5.19 −5.30	50 700	51.8	−6.3 (*1.1*)	+3.0 (*2.7*)	Irregular very dark adherent scale with dark green areas and some surface dirt.
Altoona No. 2.....	533.97 533.14	−0.50 −0.53	−1.45 −1.45	−3.07 −3.08	51 500	51.3	−4.8 (*1.0*)	+2.0 (*2.8*)	Uniform greenish-black adherent light scale with considerable dirt and soot.
New York City No. 4.....	536.03 535.71	−1.25 −1.26	−3.39 −3.44	−7.12 −7.05	51 100	52.3	−5.5 (*1.0*)	+4.0 (*2.8*)	Mottled dark green adherent scale.
Rochester No. 6.....	531.53 533.94	+0.15 +0.19	+0.71 +0.81	+1.55 +1.73	52 300	51.7	−3.3 (*0.9*)	+2.8 (*3.1*)	Mottled "peacock" colored adherent scale.
Sandy Hook No. 5.....	534.10 532.12	+0.26 +0.24	+0.03 −0.01	−0.59 −0.66	51 800	51.5	−4.3 (*1.0*)	+2.4 (*2.8*)	Olive green adherent scale with band of light-green scale at top.
Key West No. 7.....	532.05 535.19	+0.21 +0.22	+0.16 +0.17	+0.10 +0.10	53 200	51.5	−1.7 (*0.7*)	+2.4 (*2.8*)	Uniform red-brown adherent smooth film with green scale at edges.
La Jolla No. 9.....	533.95 534.27	+0.92 +0.94	+1.26 +1.32	+1.59 +1.67	53 300	51.8	−1.5 (*1.0*)	+3.0 (*2.7*)	Red-brown adherent film with overlying green film, green powdery scale at edges.
State College No. 3.....	533.11 538.25	−0.07 −0.07	−0.27 −0.26	−0.55 −0.55	53 200	51.7	−1.7 (*1.3*)	+2.8 (*3.1*)	Dark brown adherent smooth film with greenisk black streaks.
Phoenix No. 8.....	534.10 533.14	+0.09 +0.09	+0.04 +0.04	+0.07 +0.07	53 800	50.5	−0.6 (*1.0*)	+0.4 (*2.8*)	Uniform brownish-yellow adherent smooth film.
Material O—Duralumin (4 Cu, 0.5 Mn, 0.5 Mg, balance Al)									
Pittsburgh No. 1.....	166.17 167.37	+0.73 +0.84	+0.87 +0.96	+1.22 +1.19	60 600	13.7	−7.0 (*2.7*)	−33.2 (*13.9*)	Very dark film somewhat roughened in a pattern elongated in rolling direction; large spotted dark areas.
Altoona No. 2.....	168.35 171.77	+0.68 +0.66	+0.96 +0.94	+1.25 +1.28	60 015	12.9	−7.9 (*1.9*)	−37.1 (*7.8*)	Very dark rough film with red-brown discoloration of foreign origin.
New York City No. 4.....	165.66 164.70	+0.87 +1.04	+1.00 +1.15	+1.19 +1.29	58 595	10.6	−10.1 (*1.6*)	−48.3 (*7.8*)	Very dark rough film, much smoother than No. 6.
Rochester No. 6.....	168.41 167.83	+0.42 +0.49	+1.33 +1.39	+1.68 +1.75	62 820	14.5	−5.1 (*1.1*)	−29.3 (*4.7*)	Very dark film roughened and speckled with fine scale.
Sandy Hook No. 5.....	168.42 172.11	+1.05 +1.09	+1.41 +1.40	+1.44 +1.45	60 945	12.8	−6.5 (*0.8*)	−37.6 (*6.9*)	Mottled dark gray film very finely speckled with white powdery scale.
Key West No. 7.....	171.99 169.38	+0.87 +0.64	+1.17 +0.91	+1.49 +1.15	63 695	14.8	−2.2 (*1.9*)	−27.8 (*5.1*)	Mottled dull gray film with some underlying metallic luster, very fine white powdery surface scale.
La Jolla No. 9.....	168.13 169.30	+2.89 +2.84	+3.48 +3.42	+7.17 +5.33	40 740	2.0	−37.5 (*4.8*)	−90.3 (*4.7*)	Dull gray film, speckled with light gray granular white scale and brownish spots.
State College No. 3.....	165.99 165.00	−0.01 −0.01	−0.03 −0.03	−0.04 −0.05	65 075	19.3	+0.1 (*1.7*)	−5.9 (*5.9*)	Tarnish similar to the initial tarnish film.
Phoenix No. 8.....	167.44 169.81	+0.06 +0.10	+0.03 +0.07	+0.09 +0.13	65 350	18.3	+0.3 (*2.2*)	−1.1 (*12.2*)	Tarnish similar to the initial tarnish film, somewhat roughened.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material N				
Original....... After 6 yr.....	54 958 54 100	51.1 50.3	−1.6 (*1.0*)	−1.6 (*3.2*)
Material O				
Original....... After 6 yr.....	63 760 65 155	20.7 20.5	+2.2 (*1.0*)	−1.0 (*5.4*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
				Material P—Copper-Nickel-Zinc Alloy (75 Cu, 20 Ni, 5 Zn)					
Pittsburgh No. 1	562.71 566.41	+0.25 +0.23	−2.89 −2.52	−6.51 −6.10	50 300	31.8	−5.5 (*1.1*)	−0.6 (*4.2*)	Irregular green-black friable rough scale with considerable dirt and soot.
Altoona No. 2	571.48 570.17	−0.43 −0.43	−3.52 −3.12	−8.88 −8.12	50 500	31.8	−5.1 (*1.3*)	−0.6 (*3.2*)	Friable black scale broken off in spots with adherent brown underfilm exposed. Some dirt and soot.
New York City No. 4	570.23 569.48	−1.29 −1.34	−3.95 −4.03	−8.77 −9.16	50 000	31.3	−6.0 (*2.6*)	−2.2 (*5.7*)	Green thin scale with black spots and brown adherent underfilm exposed partially on one side.
Rochester No. 6	557.41 556.14	+0.20 +0.19	+0.71 +0.67	+0.72 +0.51	51 000	31.8	−4.1 (*1.7*)	−0.6 (*3.8*)	Mottled "peacock" colored rough scale, loosened in some areas. One specimen damaged.
Sandy Hook No. 5	570.31 570.97	+0.09 +0.10	−0.95 −1.27	−2.98 −3.78	52 000	31.5	−2.3 (*1.2*)	−1.6 (*3.7*)	Irregular gray-green friable scale over brown adherent film.
Key West No. 7	560.31 557.54	+0.08 +0.08	−0.01 −0.02	−0.14 −0.14	52 100	32.3	−2.1 (*1.3*)	+0.9 (*3.3*)	Streaked reddish-tan adherent smooth film.
La Jolla No. 9	561.62 565.95	+0.50 +0.46	+0.35 +0.30	−0.04 −0.03	52 900	31.6	−0.6 (*1.4*)	−1.3 (*3.3*)	Light-green thin smooth scale over tan adherent film.
State College No. 3	572.69 573.60	−0.06 −0.07	−0.26 −0.27	−0.61 −0.64	52 800	31.9	−0.8 (*1.6*)	−0.3 (*3.0*)	Uniform dark brown adherent smooth film.
Phoenix No. 8	560.51 562.50	+0.09 +0.11	+0.08 +0.08	+0.09 +0.11	53 000	32.2	−0.4 (*1.8*)	+0.6 (*2.8*)	Uniform olive green tarnish.
				Material Q—Copper-Nickel-Tin Alloy (70 Cu, 29 Ni, 1 Sn)					
Pittsburgh No. 1	543.95 544.16	0.00 −0.05	−2.77 −2.35	−8.23 −5.68	73 900	23.3	−5.6 (*19.0*)	+3.6 (*29.3*)	Mottled greenish-black scale peeled off in numerous spots with brown underfilm exposed, some dirt on surface.
Altoona No. 2	549.83 553.56	−0.74 −0.69	−2.66 −2.65	−6.85 −7.01	74 100	23.3	−5.4 (*9.6*)	+3.6 (*27.9*)	Brown-black rough scale peeled off in spots with underlying brown film exposed.
New York City No. 4	541.46 546.45	−1.34 −1.35	−4.40 −4.41	−10.27 −10.26	76 700	21.0	−2.0 (*7.9*)	−6.7 (*23.6*)	Green-gray film with black spots and dirt streaks.
Rochester No. 6	542.42 542.75	+0.13 +0.17	+0.78 +0.77	+1.22 +1.20	75 700	23.3	−3.3 (*9.4*)	+3.6 (*27.3*)	Mottled "peacock" colored adherent rough scale.
Sandy Hook No. 5	549.01 550.11	+0.10 +0.10	−0.80 −0.79	−2.91 −2.89	75 500	24.2	−3.6 (*9.8*)	+7.6 (*30.0*)	Green-gray scale with brown spots exposed near edges.
Key West No. 7	545.10 545.07	+0.05 +0.07	−0.01 −0.01	−0.10 −0.09	72 800	27.5	−7.0 (*7.3*)	+22.2 (*20.8*)	Uniform red-tan adherent smooth film with trace of green scale along edges.
La Jolla No. 9	544.72 544.59	+0.31 +0.33	+0.17 +0.14	−0.23 −0.27	76 300	24.2	−2.6 (*9.0*)	+7.6 (*26.6*)	Light green smooth thin scale over tan adherent film.
State College No. 3	543.55 544.53	−0.11 −0.11	−0.31 −0.31	−0.64 −0.63	80 000	31.8	+2.2 (*11.3*)	−3.1 (*32.9*)	Uniform dark brown adherent smooth film.
Phoenix No. 8	544.42 545.23	+0.08 +0.08	+0.05 +0.05	−0.07 −0.06	78 500	23.0	+0.3 (*11.0*)	+2.2 (*30.1*)	Uniform grayish-brown tarnish.

CHANGES DUE TO AGING
(STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
		Material P		
Original After 6 yr.	54 350 53 200	31.5 32.0	−2.1 (*1.2*)	+1.6 (*3.1*)
		Material Q		
Original After 6 yr.	76 792 78 300	24.2 22.5	+2.0 (*9.3*)	−7.0 (*2.8*)

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[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks[b]
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material S—Nickel-Copper Alloy (65 Ni, 32 Cu, 2 Fe, 1 Mn)									
Pittsburgh No. 1	557.73 551.88	−1.14 −1.12	−3.00 −2.94	−6.68 −6.56	78 700	35.8	−0.4 (*1.8*)	−0.3 (*2.4*)	Black heavy film.
Altoona No. 2	555.91 546.07	−1.10 −1.09	−3.88 −3.88	−8.32 −8.31	77 700	35.8	−1.7 (*1.1*)	−0.3 (*1.5*)	Black heavy film.
New York City No. 4	542.23 548.76	−1.61 −1.65	−4.42 −4.45	−8.95 −9.08	76 750	36.7	−2.9 (*1.4*)	+2.2 (*1.7*)	Yellowish-brown smooth film.
Rochester No. 6	541.65 538.20	−0.16 −0.17	−0.59 −0.60	−1.55 −1.56	78 800	35.2	−0.3 (*1.7*)	−2.1 (*3.1*)	Iridescent heavy film.
Sandy Hook No. 5	541.51 548.25	−0.44 −0.41	−1.87 −1.73	−4.22 −4.14	78 000	36.3	−1.3 (*0.8*)	+1.1 (*3.0*)	Yellowish powdery film with metallic luster.
Key West No. 7	556.84 563.58	−0.10 −0.08	−0.24 −0.23	−0.63 −0.59	79,000	35.9	−0.1 (*1.1*)	0 (*1.7*)	Greenish thin film with metallic luster.
La Jolla No. 9	554.44 553.40	+0.15 +0.19	−0.25 −0.23	−0.77 −0.71	79 200	35.6	+0.2 (*1.7*)	−0.8 (*2.4*)	General tarnish with spots of light green scale.
State College No. 3	550.61 543.71	−0.15 −0.16	−0.37 −0.39	−0.76 −0.79	79 000	36.4	−0.1 (*1.2*)	+1.4 (*1.7*)	Very slight tarnish.
Phoenix	555.35 546.33	+0.02 +0.02	−0.05 −0.05	−0.07 −0.07	79 050	35.5	0 (*1.0*)	−1.1 (*1.6*)	Slight tarnish.
Material T—Commercial Nickel (99+ Ni)									
Pittsburgh No. 1	560.76 564.43	−3.90 −3.86	−10.82 −10.71	−23.05 −22.79	68 700	36.7	−5.9 (*1.8*)	−0.3 (*1.8*)	Heavy dark film.
Altoona No. 2	565.49 565.60	−3.83 −3.95	−11.76 −12.04	−24.86 −25.48	67 300	36.6	−7.8 (*1.3*)	−0.5 (*1.4*)	Heavy dark film with patches of slight scale.
New York City No. 4	561.82 565.53	−5.01 −5.07	−12.48 −12.58	−24.46 −24.45	67 600	36.3	−7.4 (*1.4*)	−1.4 (*1.2*)	Smooth heavy film with slightly mottled appearance.
Rochester No. 6	561.22 566.87	−0.53 −0.54	−2.03 −2.06	−5.52 −5.76	71 500	36.5	−2,0 (*1.4*)	−0.8 (*1.9*)	Smooth mottled film.
Sandy Hook No. 5	561.51 562.28	−0.74 −0.74	−2.36 −2.39	−5.10 −5.14	72 000	37.0	−1.4 (*1.2*)	+0.5 (*2.3*)	Smooth slate-colored film.
Key West No. 7	564.13 559.16	−0.14 −0.14	−0.41 −0.41	−0.75 −0.75	72 950	36.7	−0.1 (*1.2*)	−0.3 (*1.8*)	Very light film, metallic luster.
La Jolla No. 9	563.82 563.36	+0.08 +0.10	−0.19 −0.19	−0.53 −0.57	72 900	36.3	−0.1 (*1.3*)	−1.4 (*2.6*)	Slight speckling of powdery scale, underlying tarnish.
State College No. 3	566.06 562.88	−0.12 −0.12	−0.39 −0.38	−0.97 −0.98	73 650	37.0	+0.9 (*1.2*)	+0.5 (*0.8*)	Very slight tarnish.
Phoenix No. 8	564.94 561.31	0.00 0.00	−0.06 −0.06	−0.09 −0.10	72 800	35.9	−0.3 (*1.1*)	−2.4 (*1.0*)	Slight tarnish.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material S				
Original After 6 yr.	79 400 79 050	35.6 36.8	−0.4 (*1.6*)	+0.8 (*1.9*)
Material T				
Original After 6 yr.	71 100 73 000	35.8 36.8	+4.0 (*1.2*)	+2.8 (*1.8*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] The surfaces of all specimens were smooth, any corrosion product present was powdery and easily brushed off.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material U—Chemical Lead (99.92 Pb, 0.06 Cu)									
Pittsburgh No. 1	714.93 717.95	+0.14 +0.03	−0.21 −0.24	−1.04 −1.37	2367	41.8	+3.0 (*1.4*)	+0.5 (*14.6*)	Dark gray film, deposits of some tar and silt severe mechanical damage of specimens.[b]
Altoona No. 2	713.98 711.36	−0.21 −0.24	−0.66 −0.76	−1.42 −1.67	2338	41.1	+1.7 (*1.5*)	−1.2 (*10.1*)	Black sooty film with a tinge of red of foreign source.[b]
New York City No. 4	715.64 713.77	−0.04 −0.11	−0.47 −0.89	−1.05 −1.52	2382	40.3	+3.7 (*1.8*)	−3.1 (*10.0*)	Dark gray film with some light gray areas.[b]
Rochester No. 6	737.46 738.12	+0.04 0.00	0.00 −0.03	−0.04 −0.12	2366	34.3	+3.0 (*1.7*)	−17.5 (*27.1*)	Dark gray film with a few "spatterings" of white powdery scale.[b]
Sandy Hook No. 5	704.78 701.72	−0.13 −0.17	−1.19 −1.11	−2.34 −2.32	2373	40.3	+3.3 (*1.9*)	−3.1 (*11.9*)	Light gray film with "spatterings" of white powdery scale.[b]
Key West No. 7	720.15 723.72	−0.50 −0.45	−1.19 −1.24	−2.89 −2.97	2357	42.2	+2.6 (*1.8*)	+1.4 (*10.5*)	Thin powdery white scale over light gray film.[b]
La Jolla No. 9	717.24 716.29	+0.29 +0.33	+0.10 −0.14	−0.64 −0.60	2392	37.6	+4.1 (*1.6*)	−9.6 (*9.7*)	Light gray film with white powdery scale at edges and in streaks.[b]
State College No. 3	718.49 718.33	+0.02 −0.10	−0.50 −0.64	−0.93 −1.18	2375	39.8	+3.3 (*1.9*)	−4.3 (*11.0*)	Dark gray film with "spatterings" of white powdery scale.[b]
Phoenix No. 8	712.98 711.92	−0.04 −0.03	−0.17 −0.20	−0.37 −0.36	2398	43.2	+4.4 (*1.7*)	+3.6 (*12.8*)	Medium gray film with considerable iridescent tarnish, 3 of 4 sides, white powdery scale along scratches from mechanical damage.[b]
Material Z—Aluminum-Magnesium-Silicon Alloy (98 Al, 0.5 Mg, 1 Si)									
Pittsburgh No. 1	160.61 160.19	+0.22 +0.21	+0.27 +0.28	+0.38 +0.54	38 445	15.2	−8.8 (*2.0*)	−36.1 (*7.9*)	Show some mechanical damage, surface generally dirty and roughened with very fine pattern of hard adherent scale.
Altoona No. 2	162.66 163.26	+0.25 +0.22	+0.56 +0.47	+0.86 +0.74	36 895	13.3	−12.5 (*3.0*)	−44.2 (*9.8*)	Show some mechanical damage, surface generally dark and dirty and roughened with very fine pattern of hard adherent scale.
New York City No. 4	163.05 167.63	+0.32 +0.33	+0.41 +0.39	+0.64 +0.59	37 520	13.8	−11.0 (*3.4*)	−42.0 (*6.6*)	Surface dirty and generally roughened with very fine pattern of hard adherent scale.
Rochester No. 6	160.89 159.59	+0.11 +0.09	+0.21 +0.20	+0.37 +0.38	39 805	14.2	−5.6 (*1.5*)	−40.3 (*9.7*)	Dull dirty film speckled with small spots of darker hard adherent scale.
Sandy Hook No. 5	169.40 168.85	+0.22 +0.21	+0.33 +0.27	+0.34 +0.27	37 985	13.2	−9.9 (*2.8*)	−44.6 (*9.7*)	Dull dirty film, brownish cast, speckled with fine spots of darker hard adherent scale, more severe attack at edges.
Key West No. 7	166.85 167.80	+0.13 +0.09	+0.16 +0.14	+0.30 +0.25	40 955	12.3	−2.8 (*2.3*)	−48.4 (*7.6*)	Iridescent film speckled with "bird tracks" of fairly hard whitish scale.
La Jolla No. 9	162.34 162.32	+0.78 +0.85	+0.96 +1.00	+1.75 +1.68	30 200	4.4	−28.5 (*5.5*)	−81.5 (*7.1*)	Dull gray, thin scale with uniformly distributed mounds of heavier granular scale, 20 per cent of remaining area still shows metallic luster.
State College No. 3	160.31 167.56	−0.01 −0.01	−0.03 −0.02	−0.05 −0.04	41 310	21.5	−2.2 (*1.7*)	−9.7 (*13.9*)	Generally discolored but still showing metallic luster having a brownish cast from initial heat-treatment film.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material U				
Original	2 582	43.6		
After 6 yr.	2 298	41.6	−11.0 (*1.9*)	−4.6 (*9.6*)
Material Z				
Original	39 975	23.9		
After 6 yr.	42 170	23.8	+11.1 (*1.2*)	−0.4 (*1.8*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] Pitting or roughness insignificant in all cases. In all cases sheets buckled due to inadequate support.

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elonga-tion, per cent	Tensile Strength[a]	Percentage Elongation[a]	
				Material AA—Commercial Zinc (Prime Western Grade, 99 Zn, 0.85 Pb)					
Pittsburgh No. 1.....	445 30 469.72	−2.21 −2.30	−6.41 −6.62	−14.32 −15.02	25 700	29.1	−12.6 (*0.8*)	−18.3 (*22.1*)	Uniform dark brown thin film.
Altoona No. 2.....	443.15 442.92	−2.67 −2.73	−8.49 −8.63	−18.66 −19.08	24 900	25.9	−15.3 (*0.6*)	−27.3 (21.2)	Thin gray film with some discoloration, black deposit at edges together with considerable reddish-brown deposit.
New York City No. 4.....	440.55 447.63	−3.27 −3.23	−9.61 −9.48	−21.35 −21.10	25 500	32.0	−13.3 (*0.7*)	−10.1 (*23.3*)	Uniform light gray film with scattered black specks and areas of larger light brown spots.
Rochester No. 6.....	467.35 466.77	−0.20 −0.24	−0.97 −1.12	−2.85 −3.29	27 700	25.0	−5.8 (*0.6*)	−29.8 (*25.9*)	Thin discolored gray film with scattered black specks and brown vertical streaks.
Sandy Hook No. 5.....	467.23 466.70	−0.45 −0.45	−2.31 −2.38	−5.27 −5.35	27 600	35.2	−6.1 (*0.6*)	−1.1 (*25.4*)	Uniform light gray very thin film.
Key West No. 7.....	438.87 468.10	+0.20 +0.31	+0.04 +0.06	−0.03 0.00	28 500	32.5	−3.1 (*0.8*)	−8.7 (*21.5*)	Medium gray film with widely scattered small specks of white scale and white scale at edges.
La Jolla No. 9.....	441.13 468.47	+2.68 +3.10	+4.88 +5.21	+7.29 +7.96	23 600	1.0	−19.7 (*0.4*)	−97.2 (*29.6*)	Gray film with numerous specks of white scale increasing in size and number towards edges, very heavy white scale on edges.
State College No. 3.....	467.25 468.17	−0.06 −0.11	−1.05 −1.07	−2.83 −2.88	27 800	33.9	−5.4 (*0.5*)	−4.8 (*22.1*)	Uniform dark gray film with heavy tarnish in some areas.
Phoenix No. 8.....	468.65 469.38	+0.11 +0.12	+0.04 +0.04	+0.01 +0.04	28 600	38.2	−2.7 (*0.6*)	+7.3 (*23.3*)	Uniform gray heavy tarnish.
				Material BB—Commercial Zinc (High Grade, 99.9+ Zn)					
Pittsburgh No. 1.....	447.17 448.80	−2.35 −2.34	−6.93 −7.02	−16.30 .....[b]	16 600	53.0	−11.7 (*1.1*)	−8.8 (*5.5*)	Uniform brown thin film with some dark discoloration and scattered dark specks, one specimen only, 1-BB-1.
Altoona No. 2.....	445.89 446.97	−2.84 −2.80	−8.86 −8.90	−20.97 −20.94	15 900	48.6	−15.4 (*1.4*)	−16.4 (*6.5*)	Thin gray film with some discoloration, black deposit at edges together with some reddish brown deposit.
New York City No. 4.....	447.03 445.93	−3.65 −3.60	−10.49 −10.40	−22.22 −23.10	16 500	53.0	−12.2 (*1.1*)	−8.8 (*4.8*)	Uniform light gray film with scattered black specks and areas of larger light brown spots.
Rochester No. 6.....	445.98 446.57	−0.26 −0.26	−1.31 −1.31	−4.00 −4.01	17 400	55.9	−7.5 (*1.0*)	−3.8 (*5.6*)	Thin discolored gray film with scattered black specks and brown vertical streaks, brown stain on lower edge.
Sandy Hook No. 5.....	446.31 447.16	−0.49 −0.59	−2.58 −2.84	−5.59 −6.00	17 400	55.3	−7.5 (*1.1*)	−4.8 (*3.6*)	Uniform light gray very thin film.
Key West No. 7.....	450.16 449.96	+0.13 +0.13	−0.19 −0.19	−0.53 −0.48	17 800	56.3	−5.3 (*1.3*)	−3.1 (*5.0*)	Very thin gray film with widely scattered small specks of white scale and white scale at edges.
La Jolla No. 9.....	448.72 448.76	+2.98 +3.10	+4.89 +4.69	+6.85 +6.59	16 300[c]	31.8[c]	−13.3 (*2.7*)	−45.3 (*12.9*)	Gray film with numerous specks of white scale increasing in size and number toward edges, very heavy white scale at edges.
State College No. 3.....	448.13 449.37	−0.27 −0.27	−1.30 −1.28	−3.26 −3.17	18 000	59.6	−4.3 (*1.3*)	+2.6 (*7.1*)	Uniform light gray film with tarnish in some areas.
Phoenix....... No. 8.....	445.33 448.39	+0.08 +0.08	0.00 0.00	+0.17 +0.09	18 100	58.9	−3.7 (*1.1*)	+1.4 (*5.7*)	Specimens badly warped, uniform gray heavy tarnish, some irregular white scale and light brown powder suggests contact with another surface.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elonga-tion, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
		Material AA		
Original....... After 6 yr....	29 900 29 400	34.3 35.6	−1.7 (*0.9*)	+3.8 (*22.2*)
		Material BB		
Original....... After 6 yr....	18 280 18 800	58.5 58.1	+2.8 (*1.2*)	−0.7 (*5.5*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] Specimen missing due to Pittsburgh flood.

[c] Based on one test specimen only, other five specimens broke in grips.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material CC—Lead-Antimony Alloy (1 per cent Sb)									
Pittsburgh No. 1	743.08 704.98	0.00 +0.04	−0.21 −0.14	−0.71 −0.93	3102	52.1	−1.5 (*1.7*)	−1.3 (*5.0*)	Dark gray film with some silt and tar deposits; severe distortion and mechanical damage.[b]
Altoona No. 2	713.45 711.74	−0.15 −0.16	−0.56 −0.41	−1.46 −1.10	3062	47.0	−2.7 (*1.9*)	−11.0 (*7.9*)	Black sooty film flaked off where specimens are bent.[b]
New York City No. 4	712.83 709.90	−0.02 0.00	−0.26 −0.24	−0.68 −0.78	3133	49.3	−0.5 (*1.9*)	−6.6 (*4.2*)	Uniform very dark gray film.[b]
Rochester No. 6	708.67 706.53	+0.03 +0.02	+0.08 +0.06	+0.08 +0.11	3082	43.7	−2.1 (*2.0*)	−17.2 (*7.0*)	Dark gray film.[b]
Sandy Hook No. 5	714.46 712.77	−0.04 −0.16	−0.56 −0.54	−1.28 −1.29	3115	54.0	−1.0 (*1.9*)	+2.3 (*7.3*)	Light gray film with whitish scale at edges.[b]
Key West No. 7	713.08 713.61	−0.33 −0.34	−0.66 −0.89	−1.73 −1.98	3087	52.0	−1.9 (*1.9*)	−1.5 (*12.0*)	Light gray film blending into white scale at edges.[b]
La Jolla No. 9	710.53 712.43	+1.37 +0.77	+1.17 +0.74	+1.09 +1.23	3078	45.3	−2.2 (*1.9*)	−14.2 (*10.3*)	Whitish film, scaly in spots. Spots of green stain of foreign origin (?).[b]
State College No. 3	714.06 715.01	−0.21 −0.20	−0.53 −0.59	−1.07 [c]	3137	49.8	−0.4 (*2.0*)	−5.7 (*9.7*)	Tarnish with small amount of white film, No. 2 specimen missing.[b]
Phoenix No. 8	711.18 711.21	−0.05 −0.03	−0.18 −0.17	+0.30 −0.07	3021	52.7	−4.0 (*2.0*)	−0.2 (*10.8*)	Uniform light gray film, some silt deposit.[b]
Material EE—Commercial Tin (99.85+ Sn)									
Pittsburgh No. 1	464.38 463.64	+0.33 +0.32	+0.39 +0.66	.....[c] +1.45	3035	61.8	−12.0 (*4.3*)	−1.0 (*17.6*)	Severely distorted; deposit of some tar and silt. White spotty film, gray near edges. (One specimen missing.)[d]
Altoona No. 2	469.01 462.55	+0.45 +0.46	+1.27 +1.27	+2.42 +2.57	2940	61.5	−14.8 (*3.2*)	−1.4 (*19.8*)	Black heavy film with white pitted scale, tinge of red (foreign source) at edge.[d]
New York City No. 4	470.83 470.43	+0.50 +0.52	+0.89 +0.92	+1.48 +1.49	3061	60.7	−11.3 (*3.0*)	−2.7 (*24.6*)	Dirty dark gray film, small amount white pitted scale.[d]
Rochester No. 6	464.92 466.23	+0.33 +0.32	+0.53 +0.55	+0.87 +0.88	3145	59.1	−8.9 (*2.2*)	−5.3 (*15.0*)	Spotty whitish tarnish, few pits.[d]
Sandy Hook No. 5	470.64 472.62	+1.04 +1.00	+1.24 +1.19	+2.20 +2.07	2945	41.1	−14.6 (*3.4*)	−34.1 (*15.2*)	Surface speckled with white scaly spots with pits beneath.[d]
Key West No. 7	465.64 467.58	+0.43 +0.47	+1.12 +1.17	+2.74 +2.82	3002	57.3	−13.0 (*2.3*)	−8.2 (*17.5*)	White speckled film with scale at edges.[d]
La Jolla No. 9	470.68 468.04	+1.50 +1.45	+2.40 +2.16	+3.87 +3.71	2788	20.8	−19.2 (*4.1*)	−66.8 (*26.3*)	Spotty white scale areas with pitting, yellowish spots in heaviest scale.[d]
State College No. 3	469.23 471.13	+0.19 +0.17	+0.22 +0.21	+0.25 +0.23	3157	68.5	−8.5 (*2.8*)	+9.8 (*16.2*)	Light film with white pitted scale.[d]
Phoenix No. 8	467.84 470.34	+0.14 +0.14	+0.19 +0.20	+0.34 +0.93	2997	59.2	−13.1 (*1.8*)	−5.1 (*21.2*)	White speckled film, slight pitting.[d]

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material CC				
Original After 6 yr.	3482 3148	45.3 52.8	−9.6 (*2.5*)	+16.5 (*4.3*)
Material EE				
Original After 6 yr.	3760 3450	60.3 62.4	−8.3 (*3.8*)	+3.5 (*16.4*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] General mechanical damage in all cases due to inadequate support. Pitting or roughness insignificant in all cases.

[c] Specimen missing.

[d] Specimens in fair condition, but some warping.

Phoenix No. 8	467.84 470.34	+0.14 +0.14	+0.19 +0.20	+0.34 +0.93	2997	59.2	−13.1 (*1.8*)	−5.1 (*21.2*)	White speckled film, slight pitting.[d]

Location	Original Weight, g.	Actual Change in Weight, g.			Tensile Properties After 6-Yr. Exposure		Percentage Change in Tensile Properties After 6 Yr.[a]		Remarks
		After 1 Yr.	After 3 Yr.	After 6 Yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	
Material FF—Aluminum-Coated Duralumin									
Pittsburgh No. 1.....	167.76 171.26	+0.20 +0.18	+0.18 +0.14	+0.12 +0.11	58 845	17.1	−1.1 (*2.2*)	−10.0 (*6.3*)	Samples show some mechanical damage, surface generally dirty and roughened with very fine pattern of hard adherent scale.
Altoona No. 2.....	167.84 170.64	+0.27 +0.24	+0.37 +0.39	+0.50 +0.47	58 965	17.4	−0.9 (*2.0*)	−8.4 (*4.0*)	Samples show some mechanical damage, surface generally dark and dirty and roughened with very fine pattern of hard adherent scale.
New York City No. 4.....	169.40 173.25	+0.35 +0.32	+0.26 +0.24	+0.17 +0.16	59 255	18.9	−0.4 (*2.2*)	−0.5 (*3.5*)	Surface dirty and generally roughened with very fine pattern of hard adherent scale.
Rochester No. 6.....	169.77 169.48	+0.12 +0.11	+0.29 +0.22	+0.66 +0.38	58 245	15.6	−2.6 (*2.4*)	−17.9 (*19.7*)	Dull dirty film speckled with small spots of darker hard adherent scale.
Sandy Hook No. 5.....	171.53 173.09	+0.20 +0.23	+0.25 +0.26	+0.14 +0.16	58 945	18.3	−0.9 (*2.6*)	−3.7 (*3.5*)	Dull dirty film speckled with fine spots of darker hard adherent scale, dark scale along edges.
Key West No. 7.....	172.96 167.17	+0.09 +0.07	+0.14 +0.12	+0.20 +0.18	59 855	18.8	+0.6 (*2.4*)	−1.1 (*4.4*)	About 50 per cent of surface shows metallic luster; remainder, gray thin film with light scale spots resembling bird tracks, heavier scale near edges.
La Jolla No. 9.....	172.22 170.88	+0.62 +0.63	+0.55 +0.60	+1.13 +1.14	59 565	18.6	+0.2 (*2.0*)	−2.1 (*4.4*)	Dull gray thin scale with uniformly distributed mounds of heavier granular scale, 30 per cent of area still shows metallic luster.
State College No. 3.......	169.45 171.61	−0.01 +0.09	−0.03 +0.07	−0.05 +0.05	59 500	17.9	+0.1 (*2.5*)	−5.8 (*6.2*)	Generally discolored but still showing metallic luster, uniformly distributed small light gray spots over the mottled tarnished background.
Phoenix No. 8.....	170.06 168.98	+0.03 +0.03	+0.01 +0.01	+0.03 +0.03	59 080	19.3	−0.7 (*2.7*)	+1.6 (*3.5*)	Metallic luster generally visible over entire surface with a mottled pattern of gray spots, fine black spots uniformly distributed on numbered side.
Material HH—Commercial Zinc (Special High Grade 99.99+ per cent Zn)									
Pittsburgh No. 1.....	446.02 430.83	−2.52 −3.29	−7.59 −7.98	−17.49 −17.30	16 350	50.0	−14.4 (*1.5*)	−7.1 (*10.9*)	Thin brown film discolored with black deposit
Altoona No. 2.....	436.54 435.41	−2.92 −2.83	−9.15 −9.03	−20.72 −20.85	16 100	45.5	−15.7 (*1.9*)	−15.4 (*9.6*)	Light gray film with black deposit at edges and also some red-brown deposit of foreign origin.
New York City No. 4.....	432.61 432.64	−3.68 −3.66	−10.81 −10.77	−23.58 −23.53	16 550	47.7	−13.3 (*2.0*)	−11.4 (*7.0*)	Uniform light gray film with scattered black specks and areas of larger light brown spots.
Rochester No. 6.....	435.38 433.95	−0.22 −0.22	−1.25 −1.24	−4.12 −4.15	18 100	45.3	−5.2 (*2.1*)	−15.9 (*7.8*)	Uniform dark gray film with some discoloration and scattered black specks.
Sandy Hook No. 5.....	434.37 433.67	−0.44 −0.46	−2.57 −2.60	−5.83 −5.89	18 150	50.0	−5.0 (*2.1*)	−7.1 (*9.3*)	Uniform light gray very thin film.
Key West No. 7.....	435.58 435.64	+0.14 +0.22	−0.18 −0.08	−0.54 −0.42	18 650	49.3	−2.4 (*1.6*)	−8.4 (*5.4*)	Very thin gray film with widely scattered small specks of white scale and white scale at edges.
La Jolla No. 9.....	435.85 434.91	+2.53 +2.40	+3.96 +3.75	+5.62 +5.27	16 350	23.9	−14.4 (*6.2*)	−55.7 (*23.5*)	Gray film with specks of white scale increasing in size and number toward edges, very heavy white scale at edges.
State College No. 3.....	432.89 430.75	−0.13 −0.07	−1.32 −1.28	−3.60 −3.45	18 250	50.5	−4.5 (*2.2*)	−6.2 (*9.6*)	Uniform light gray film with tarnish in some areas.
Phoenix No. 8.....	442.17 439.06	+0.09 +0.09	0.00 −0.01	−0.05 −0.05	18 750	53.0	−1.8 (*2.1*)	−1.5 (*6.4*)	Uniform gray heavy tarnish.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
Material FF				
Original.......	58 790	19.5		
After 6 yr.....	59 470	19.0	+1.2 (*2.0*)	−2.6 (*2.4*)
Material HH				
Original.......	18 800	51.6		
After 6 yr.....	19 100	53.8	+1.6 (*2.1*)	+4.3 (*6.4*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

REPORT OF COMMITTEE B-4
ON
ELECTRICAL-HEATING, ELECTRICAL-RESISTANCE AND ELECTRIC-FURNACE ALLOYS

Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys held two meetings during the year, in Washington, D. C., on November 4 and 5, 1937, and in New York City on February 17 and 18, 1938, in addition to the meeting held during the annual meeting of the Society.

The committee consists of 48 members, of whom 22 are classified as producers, 20 as consumers and 6 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

The committee recommends that the following methods of test be accepted for publication as tentative, as appended hereto:[1]

Tentative Method of Test for Temperature Resistance Constants of Sheet Materials for Shunts and Precision Resistors, proposed by Subcommittee II, and

Tentative Method for Bend Testing of Wire (Wire for Radio Tubes and Incandescent Lamps), proposed by Subcommittee IV.

Revision of Standard:

The committee recommends the immediate revision of the Standard Accelerated Life Test for Metallic Materials for Electrical Heating (B 76 – 36),[2] proposed by Subcommittee I as indicated below. The necessary nine-tenths vote at the annual meeting is accordingly requested in order that the revision may be referred to letter ballot of the Society.

Section 1.—Change this section by the omission of all but the first sentence so that it will read as follows, the material to be omitted being enclosed in brackets:

1. This method covers the determination of the resistance to oxidation at high temperatures under intermittent heating of metallic materials for electrical heating. [The method is applicable to two general classes of metallic materials for electrical heating, as follows:]

[*Class A.*—Alloys suitable for commercial service up to 1100° C. (2012° F.).]

[*Class B.*—Alloys suitable for commercial service up to 900° C. (1652° F.).]

[NOTE.—A typical class *A* alloy is one of nominal composition 80 per cent nickel and 20 per cent chromium; a typical class *B* alloy is one of nominal composition 60 per cent nickel, 15 per cent chromium and 25 per cent iron.]

Section 2 (a).—Change the note under Paragraph (*a*) of this section from its present form: namely,

NOTE.—The cover or shield over the wire must be a tight fit on the board and the slide and pyrometer tube should fit snugly to prevent leakage of air at this point while observations are being taken, as even a slight draught of air in contact with the specimen will cause excessive variation in the length of life.

to read as follows:

NOTE.—The enclosure shall fit tightly on the board and the glass slide shall fit snugly to prevent leakage of air at this point during the operation of the test, as even a slight draft of air in contact with the specimen will cause excessive variation in length of life.

Change Paragraph (*c*) of Section 2

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[1] See pp. 724 and 719.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 734.

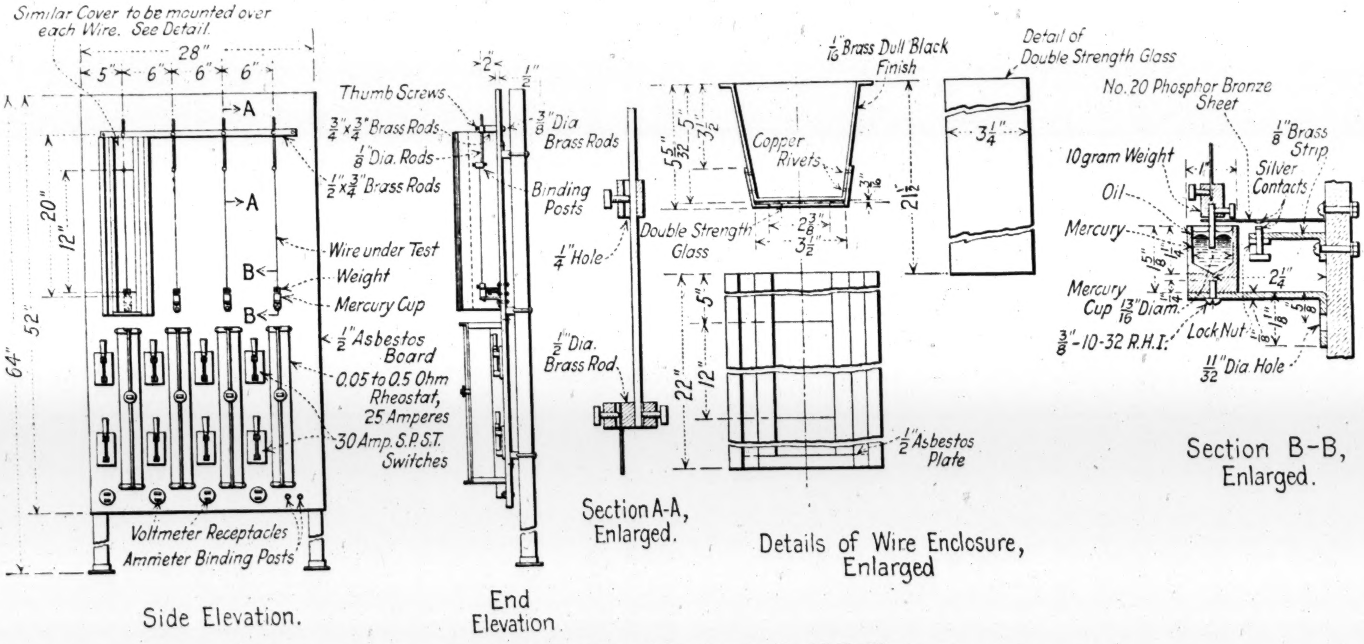
Similar Cover to be mounted over each Wire. See Detail.
28"
5"
6"
6"
6"
A
A
B
B
20"
12"
52"
64"
Thumb Screws
3/4" x 3/4" Brass Rods
1/8" Dia. Rods
1/2" x 3/4" Brass Rods
Wire under Test
Weight
Mercury Cup
1/2" Asbestos Board
0.05 to 0.5 Ohm Rheostat, 25 Amperes
30 Amp. S.P.S.T. Switches
Voltmeter Receptacles
Ammeter Binding Posts
Side Elevation.
2"
1/2"
3/8" Dia Brass Rods
Binding Posts
End Elevation.
1/4" Hole
1/2" Dia. Brass Rod
Section A-A, Enlarged.
1/16" Brass Dull Black Finish
Copper Rivets
5 5/32"
5"
3 1/2"
3/16"
2 3/8"
3 1/2"
21 1/2"
Double Strength Glass
5"
12"
22"
1/2" Asbestos Plate
Details of Wire Enclosure, Enlarged
Detail of Double Strength Glass
3 1/4"
No. 20 Phosphor Bronze Sheet
1/8" Brass Strip
10 gram Weight
Oil
Mercury
1"
Silver Contacts
1 5/8"
1/4"
2 1/4"
Mercury Cup 13/16" Diam.
3/8"-10-32 R.H.I.
Lock Nut
1/8"
5/8"
11/32" Dia. Hole
Section B-B, Enlarged.

FIG. 1.—Test Board for Accelerated Life Test.

from its present form: namely, retaining the note which follows this paragraph,

(*c*) *Lower Terminal.*—The mercury cup constitutes the lower terminal. A weight which will develop a stress of 35 lb. per sq. in. in the wire shall be attached to the lower end of the specimen, as shown in Fig. 1. This is equivalent to a weight of 10 g. for wire 0.0285 in. in diameter.

to read as follows:

(*c*) *Lower Terminal.*—The mercury cup constitutes the lower terminal. A weight of 10 g. shall be attached to the lower end of the specimen.

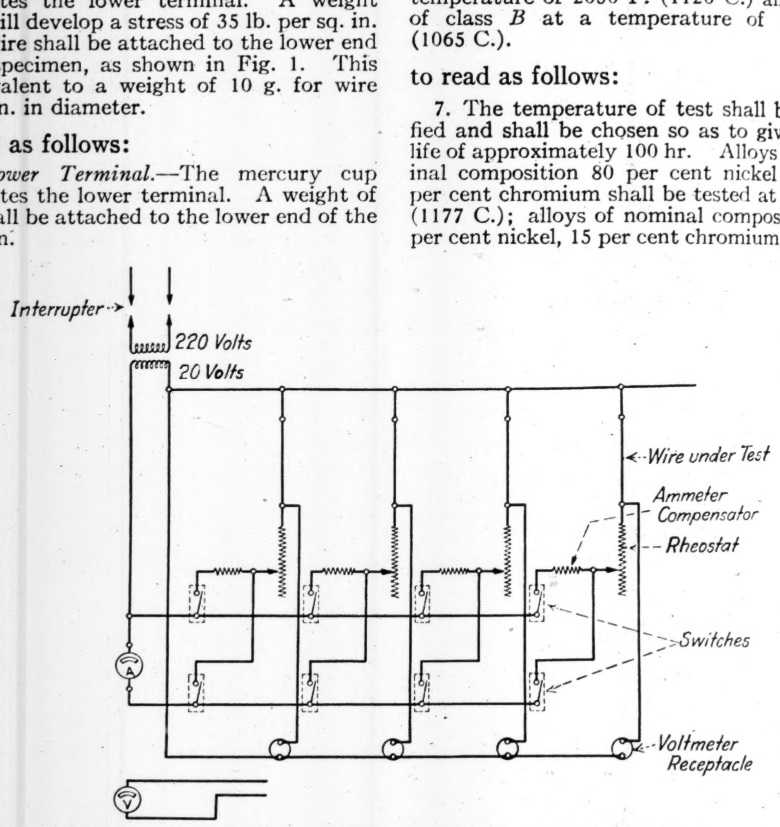

FIG. 2.—Electrical Circuit Diagram for Accelerated Life Test.

Figure 1.—Replace this figure, which shows the test board for the accelerated life test, by the accompanying Fig. 1.

Figure 2.—Replace this figure, which shows the electrical circuit diagram for accelerated life test, by the accompanying Fig. 2.

Section 3.—Change the note under paragraph (*d*) to read as follows by the omission of the word in brackets:

NOTE.—A [tubular,] wire-wound or ribbon-wound sliding contact rheostat, having a working range of adjustability from approximately 0.05 to 0.5 ohms, provides for testing wires within a considerable range of size and resistivity.

Section 7.—Change this section from its present form: namely,

7. Alloys of class *A* shall be tested at a temperature of 2050 F. (1120 C.) and alloys of class *B* at a temperature of 1950 F. (1065 C.).

to read as follows:

7. The temperature of test shall be specified and shall be chosen so as to give a test life of approximately 100 hr. Alloys of nominal composition 80 per cent nickel and 20 per cent chromium shall be tested at 2150 F. (1177 C.); alloys of nominal composition 60 per cent nickel, 15 per cent chromium, and 25 per cent iron shall be tested at 2050 F. (1120 C.).

Appendix.—In the Appendix delete the present fifth and sixth paragraphs under the section on Temperature and the two paragraphs comprising the section on Specimen Enclosure and replace by the following:

To determine the temperature accurately, the disappearing filament type optical pyrometer may be used and the desired magnification can be obtained by substituting for the standard objective lens another lens having approximately one half its focal length. The temperature of the wire under test is very greatly affected by drafts. The enclosure, therefore, should be left in place at all times during the temperature observation and the pyrometer reading made directly through the glass front of the enclosure.

In taking this reading through the glass front, it is necessary to allow for the reflection and absorption of the glass. Reflection at the surface of the glass is the principal cause of error. This effect is nearly independent of the kind and thickness of the glass. Reflection from external light sources shall be avoided. A correction of 10 F. (5.5 C.) shall be added to the temperature as observed. The glass slide shall be kept clean at all times to avoid increase in the absorption of light.

Tentative Standard Continued as Tentative:

It is recommended that the Tentative Method of Test for Linear Expansion of Metals (B 95 - 35 T) be continued for one more year as tentative.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 48 members; 36 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Method of Test for Temperature Resistance Constants of Sheet Materials for Shunts and Precision Resistors	28	0	8
Method for Bend Testing of Wire (Wire for Radio Tubes and Incandescent Lamps)	25	1	10
II. REVISION OF STANDARD			
Accelerated Life Test for Metallic Materials for Electrical Heating (B 76 - 36), immediate adoption	26	0	10

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Life Tests (J. W. Harsch, chairman).—In the Standard Accelerated Life Test for Metallic Materials for Electrical Heating (B 76 - 36), in order to prevent temperature variations it has been found necessary to complete the enclosure of the test specimen with a glass front as a protection against drafts of air and to permit the taking of optical pyrometer readings. This has made necessary a change in Fig. 1 of the method. Also, the temperature for the test is specified to be chosen so as to give a test life of about 100 hr., instead of calling for a fixed temperature of test which would require a very long time for the testing of some alloys. To show the ammeter compensation, which previously had been incorporated in the test, the electrical circuit diagram in Fig. 2 has been changed. A revision of Standard B 76 to provide for these changes is being recommended for immediate adoption, as indicated earlier in this report.

The proposed high-temperature accelerated life test for electric furnace resistor alloys is being given a further trial in several laboratories.

Subcommittee II on Electrical Tests (P. H. Dike, chairman).—The chairman of this subcommittee since its organization in 1926, Mr. H. L. Curtis, found it necessary to withdraw from the chairmanship and Mr. P. H. Dike has been appointed in his place. The committee appreciates the very effective work which the subcommittee has accomplished under the chairmanship of Mr. Curtis.

A new Method of Test for Temperature Resistance Constants of Sheet Materials for Shunts and Precision Resistors is being submitted for publication as tentative, as mentioned earlier in this report. This method is the result of an extensive investigation carried on for several years to determine the requirements necessary to insure the proper degree of accuracy for precision resistors.

Subcommittee IV on Mechanical Tests (P. H. Brace, chairman).—After several years' work comparing various methods of making bend tests to determine the temper of wire, a Method for Bend Testing of Wire (Wire for Radio Tubes and Incandescent Lamps) has been prepared and is being submitted for publication as tentative. This method has been prepared at the request of wire and radio tube manufacturers for the purpose of determining the temper of wire used in radio tubes. Essentially the same method already is being used successfully by several companies for the purchase and inspection of large quantities of wire for this application. This method is one of the three methods of making bend tests of wires all of which were printed for information in the 1936 annual report of Committee B 4.[1]

Subcommittee V on Wrought and Cast Alloys for High-Temperature Use (C. L. Clark, chairman).—Equipment has been developed for making bend tests at high temperatures on bars for furnace structures; tests are being made at 1800 F. (980 C.).

A warpage test is being developed to determine the tendency of materials to warp when subjected to wide variations in temperature. A study of sizes and sections of specimens is being made.

Subcommittee VII on Thermostatic Metals (P. H. Brace, chairman).—The subcommittee is working on a modification of the Tentative Method of Test for Flexivity of Thermoflex (Thermostatic Metals) (B 106 - 37 T) to permit either point or knife-edge supports for the test specimen and to provide a correction factor for cross bending when knife edges are used. The present method is suitable for specimens down to 0.030 in. in thickness, but the problem of testing thinner material is being studied.

Work also is proceeding on the development of a method of test for effective modulus of elasticity.

Subcommittee VIII on Metallic Materials for Radio Tubes and Incandescent Lamps (A. L. Chapman, chairman).—Subcommittee VIII has been very active since its organization last year. The subcommittee has been limited to 20 members and is divided into the following five sections: on Strip, Wire, Tubing, Coated Material, and Powdered Materials and Liquids.

A Proposed Method of Testing Cathode Sleeves and Cathode Tubing has been prepared by this subcommittee and is being recommended for publication as information. The method appears as an Appendix to this report.

The subcommittee is now completing Methods of Testing Nickel and Nickel-Alloy Electronic Tube Filaments and a Method of Test for Brittleness of Tungsten Wire.

Subcommittee VIII has studied the various methods of making bend tests of wire which have been outlined by Subcommittee IV and requested that one of the test methods be standardized. A new Method for Bend Testing of Wire (Wire for Radio Tubes and Incandescent Lamps) is accordingly being offered for publication as tentative, as mentioned earlier in this report. The subcommittee is investigating the possibility of using the wire bend test method as a means of testing thin strip materials.

Subcommittee IX on Effect of Furnace Atmosphere on Furnace Resistors (P. H. Brace, chairman).—Many tests have been made on various alloys in different atmospheres at various temperatures in electric furnaces and the test results have been discussed. The establishment of a standard method of test for determining the effect of furnace atmospheres upon the life of furnace resistors is considered desirable to permit comparisons of resistors under various conditions. A preliminary draft of such a test has been prepared and substantial progress has been made in obtaining the information necessary for the completion of this method.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 162 (1936).

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 48 members; 36 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

DEAN HARVEY,
Chairman.

F. E. BASH,
Secretary.

APPENDIX

PROPOSED METHOD OF TESTING CATHODE SLEEVES AND CATHODE TUBING[1]

This is a **proposed method** and is published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

1. *Scope.*—These methods of test cover the testing of seamed and seamless cathode sleeves and random length cathode tubing with respect to dimensions and physical properties.

DIMENSIONS

2. (*a*) *Sampling.*—Five or more seamless or lock-seam sleeves shall be selected at random from each box.

(*b*) Five or more sections approximately 1 in. in length shall be cut from various pieces of each 500 ft., or fraction thereof, of random-length cathode tubing for dimensional tests. Each section shall be cut from a different length of tubing.

3. *Outside Dimensions.*—Outside dimensions of round or shaped sleeves or random tubing shall be checked by either a hand micrometer with a vernier reading to 0.0001 in. or a barrel micrometer reading direct to 0.0001 in. The micrometers shall conform to the requirements of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 - 36 T) of the American Society for Testing Materials.[2] When measuring, the jaw opening shall be just sufficient to prevent the sleeve or section of tubing from falling through the jaws of the micrometer. Results obtained in this way have been found to be accurate to within ±0.0001 in. Rejection shall be based only on measurements made with the barrel micrometer.

4. *Wall Thickness.*—Wall thickness of round or shaped sleeves or random tubing shall be checked by slitting open a portion of the sleeves longitudinally with a sharp instrument. The inside radius of the slit portion shall be greater than the radius of the micrometer ball. The thickness shall then be determined with a ball-point micrometer having pressure limitations of from 1 to 1.5 lb. per sq. in. and reading to 0.0001 in. The micrometer ball shall have a radius of either $\frac{1}{8}$ or $\frac{1}{16}$ in., as agreed upon between the manufacturer and the purchaser.

5. *Inside Diameter.*—The inside diameter of sleeves or random tubing shall be checked by go and no-go gages made to the tolerances specified. Burrs shall be removed from the end of the test specimen before gaging.

6. *Length.*—Cathode sleeve lengths shall be checked by hand micrometers. Burrs projecting from the ends of the cathode specimen shall be removed before checking.

7. (*a*) *Diameter of Bead.*—The bead diameter of sleeves shall be determined by hand or barrel micrometers, in accordance with Section 3.

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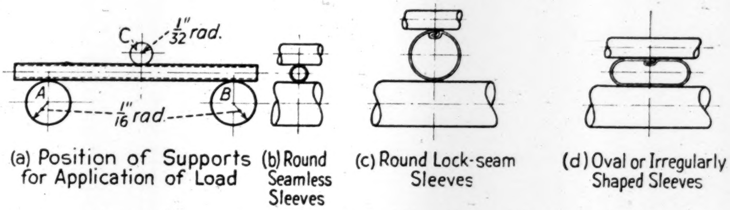
[1] Under the standardization procedure of the Society, this proposed method is under the jurisdiction of the A.S.T.M. Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1026 (1938); also 1937 Book of A.S.T.M. Tentative Standards, p. 1196.

(*b*) *Width of Bead.*—The width of bead shall be measured by means of a traveling stage comparator.

(*c*) *Location of Bead.*—The location of bead from the end of the sleeve shall be determined by means of a traveling stage comparator. The manufacturer and the purchaser shall agree as to whether the bead is to be located by the point of maximum diameter or the point at which the bead structure emerges from the surface of the cathode.



(a) Position of Supports for Application of Load (b) Round Seamless Sleeves (c) Round Lock-seam Sleeves (d) Oval or Irregularly Shaped Sleeves

FIG. 1.—Arrangement of Apparatus and Position of Specimen for Testing Cathode Sleeves and Tubing.

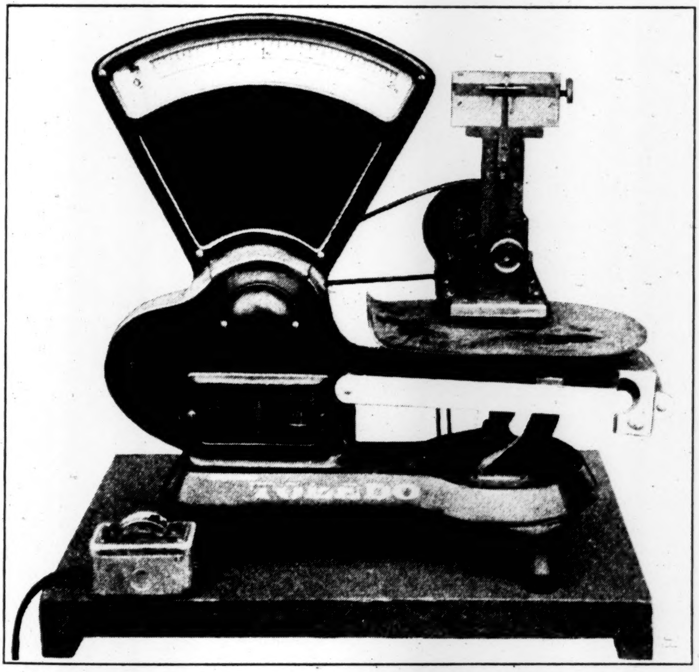


FIG. 2.—Arrangement of Apparatus for Load Determination in Stiffness Test.

STRAIGHTNESS

8. *Sampling.*—Samples shall be obtained by selecting 25 sleeves at random from each box, or by cutting that number of sleeves from various lengths of each bundle of 500 ft., or fraction thereof, of random tubing.

9. (*a*) *Procedure.*—Seamless sleeves shall be rolled with the fingers on a hard, flat surface. Those sleeves which are obviously bowed shall be subjected to further

test by dropping them through a fixture containing a hole of specified diameter. This hole shall be produced by milling half on a surface of each of two metal blocks which are then joined to complete the specified hole. The depth of this hole shall be greater than the length of the sleeve. External burrs shall be removed from the ends of the sleeves before testing. Acceptable unbeaded cathodes shall be those able to drop through the hole. Acceptable beaded cathodes shall be those able to fall through the hole as far as the bead. Rejection of sleeves or tubing for lack of straightness shall be based only on the drop test.

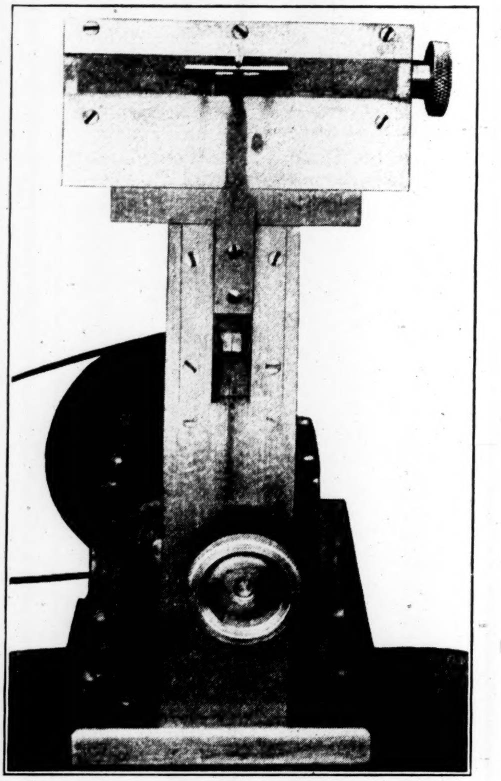


FIG. 3.—Stiffness Test Apparatus Showing Sleeve in Position for Testing.

(*b*) Lock-seam sleeves or seamless sleeves of irregular shape shall be checked for straightness by means of the drop test outlined in Paragraph (*a*) and using a hole of specified size and shape.

(*c*) Coaxiality of portions of beaded seamless sleeves located on opposite sides of the bead shall be checked by inserting a cylindrical plug. This plug shall be $\frac{1}{4}$ in. longer than the sleeve being tested, and of a diameter agreed upon between the manufacturer and the purchaser. No part of the plug shall deviate more than 0.002 in. from straightness. Burrs shall be removed from the ends of sleeves before testing. Acceptable sleeves shall be those through which the plug will drop.

STIFFNESS

10. (*a*) *Sampling.*—Five or more seamless or lock-seam sleeves shall be selected at random from each box.

(*b*) Five or more sections approximately 1 in. in length shall be cut from the various pieces of each 500 ft., or fraction thereof, of random-length cathode tubing for stiffness test. Each section shall be cut from a different length of tubing.

11. (*a*) *Procedure.*—Round seamless sleeves shall be tested for stiffness by supporting each as a simple beam and loading midway between supports. This shall be done in accordance with the arrangement shown in Fig. 1 (*a*). As shown in the figure, the supports *A* and *B* have a radius of $\frac{1}{16}$ in. and the loading device *C* a radius of $\frac{1}{32}$ in. In testing seamless sleeves the distance between centers of the supports shall be as follows:

NOMINAL OUTSIDE DIAMETER OF ROUND SLEEVES OR MINOR AXIS OF SHAPED SLEEVES	DISTANCE BETWEEN CENTERS OF THE SUPPORTS
0.015 in. up to but not including 0.035 in.	0.375 ± 0.005 in.
0.035 in. up to but not including 0.050 in.	0.500 ± 0.005 in.
0.050 in. up to but not including 0.080 in.	0.625 ± 0.005 in.
0.080 in. up to but not including 0.105 in.	0.750 ± 0.005 in.

(*b*) The load shall be applied at a rate of from 100 to 170 g. per sec. Determination of the load being supported by the sleeve shall be accomplished using an automatic scale reading direct to 10 g. and accurate to 10 g. Figure 2 shows a satisfactory arrangement for the load determination and Fig. 3 shows a sleeve in position for testing.

(*c*) Beaded sleeves shall be so located that the bead will not be in contact with the support.

(*d*) Those sleeves able to support the specified load shall be acceptable.

12. Round lock-seam sleeves shall be tested for stiffness by the procedure outlined for seamless sleeves in Section 11. The seam shall be located at the top of the sleeve, as is shown in Fig. 1 (*c*).

13. Oval or irregularly shaped sleeves shall be tested for stiffness by the procedure outlined for seamless sleeves in Section 11. The major axis shall be located in a horizontal plane. If located on the major surface, the seam of an irregularly shaped lock-seam cathode shall be located at the top. Figure 1 (*d*) shows this type of cathode in position for test.

REPORT OF COMMITTEE B-5

ON

COPPER AND COPPER ALLOYS, CAST AND WROUGHT

Committee B-5 on Copper and Copper Alloys, Cast and Wrought, held two meetings during the year, in New York City, on June 30, 1937, and in Rochester, N. Y., on March 9, 1938, with an attendance at the two meetings of 18 and 26, respectively.

The following additions and changes in membership have been approved:

A. G. Schuricht, Western Cartridge Co.,
R. W. Waring, Sperry Gyroscope Co.,
H. P. Croft, Chase Brass and Copper Co.,
A. W. Peterson, General Plate Co.,
G. R. Gohn, Bell Telephone Laboratories, Inc.,
E. H. Kelton, New Jersey Zinc Co.,
F. F. Poland to replace E. W. Rouse representing the American Smelting and Refining Co.,
T. S. Fuller to replace J. A. Capp, deceased, representing the General Electric Co.,
H. V. Schlacks, representing the Western Electric Co., Inc., to replace A. G. Johnson, who had previously succeeded E. W. Larson,
E. S. Bunn to replace R. A. Wilkins representing Revere Copper and Brass, Inc.,
H. A. Bedworth, representing the American Brass Co., and W. Reuben Webster, representing the Bridgeport Brass Co., resigned, and
E. L. Lasier, formerly of the Titanium Alloy Manufacturing Co., who had not applied for reinstatement following a change in employment, was dropped from membership.

At the present time the committee consists of 68 members, of whom 60 may vote; 24 are classified as producers, 22 as consumers, and 14 as general interest members.

Committee B-5 has been advised that the Boiler Code Committee of the American Society of Mechanical Engineers has approved for inclusion in the materials section of the A.S.M.E. Boiler Construction Code, specifications identical with the following A.S.T.M. standards and tentative standards prepared by Committee B-5:

Standard Specifications for:

S-20 Copper Plates for Locomotive Fireboxes (B 11 – 33),
S-21 Copper Bars for Locomotive Staybolts (B 12 – 33),
S-22 Seamless Copper Boiler Tubes (B 13 – 33),
S-23 Copper Pipe, Standard Sizes (B 42 – 33),
S-24 Brass Pipe, Standard Sizes (B 43 – 33),
S-41 Steam or Valve Bronze Castings (B 61 – 36), and
S-46 Composition Brass or Ounce Metal Castings (B 62 – 36).

Tentative Specifications for:

S-36 Copper-Silicon Alloy Plates and Sheets (B 96 – 36 T),
S-37 Copper-Silicon Alloy Rods, Bars and Shapes (B 98 – 36 T), and
S-47 Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (B 111 – 37 T).

RECOMMENDATIONS AFFECTING STANDARDS

Revisions of Tentative Standards:

The committee recommends revisions of three tentative specifications, as follows:

Tentative Specifications for Wrought Phosphor Bronze Bearings and Expansion Plates for Bridges and Structures (B 100 – 35 T),[1] completely revised under the title "Tentative Specifications for Rolled Copper-Alloy Bearing and Expansion Plates for Bridge and Other Structural Uses," as appended hereto.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 732 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 689.

[2] See p. 689.

Tentative Specifications for Bronze Castings for Turntables and Movable Bridges (*B 22 - 36 T*),[1] revised as follows:

Title.—Change to read as follows by the addition of the italicized words:

Tentative Specifications for Bronze Castings for Turntables and Movable Bridges *and for Bearing and Expansion Plates of Fixed Bridges.*

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

1. (*a*) These specifications cover four classes of bronze castings for turntables and movable bridges *and two classes of cast-bronze plates used in bridges and other structures for fixed and expansion bearings where motion is slow and intermittent.* [The particular class desired shall be specified in the order or agreed upon by the manufacturer and purchaser.]

(*b*) The purposes for which these classes are ordinarily used are as follows:

Class A.—For contact with hardened steel disks at low speeds under pressures not over 3000 lb. per sq. in., for example, disk bearing metals used in [turntables and] center-bearing swing bridges.

Class B.—For contact with hardened steel disks at low speeds under pressures not over 2500 lb. per sq. in., for example, disk bearing metals used in turntable and center-bearing swing bridges; [and] for contact with steel (tensile strength 60,000 lb. per sq. in., min.) at low speeds under pressures not over 1500 lb. per sq. in., for example, trunnions of movable bridges; *and for bearing and expansion plates under pressures not to exceed 2500 lb. per sq. in.*

Class C.—For ordinary machinery bearings, *and for bearing and expansion plates under pressures not to exceed 1000 lb. per sq. in.*

Class D.—For gears, worm wheels, nuts and similar parts which are subjected to other than compressive stresses.

Section 6.—In Paragraph (*a*) under compression, change the requirement for permanent set of Class A bronze from "0.06 to 0.12 in." to "0.04 to 0.12 in."

Add a new Paragraph (*d*) as follows:

(*d*) *Hardness Test.*—The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 sec. to a finished plane surface. Not less than two hardness tests shall be made for each heat.

Tentative Specifications for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (*B 111 - 37 T*),[2,3] revised as indicated below:

Section 6 (*a*).—At the end of this paragraph on microscopic examination add a new sentence to read as follows:

This requirement does not apply to hard-drawn tubes, end-annealed, in which case no microscopic examination is required.

Section 7 (*b*).—Change to read as follows by addition of the italicized words and omission of those in brackets:

(*b*) Hard-drawn tubes, *not end-annealed*, other than copper and arsenical copper, are not subject to this test [unless specified end-annealed]. *When tubes are specified end-annealed, this test is required and will be made on the annealed ends.*

Revisions of Standards:

The committee recommends for immediate adoption, the following revision of the Standard Specifications for Aluminum-Bronze Castings (B 59 - 36),[3,4] and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that this modification may be referred to letter ballot of the Society:

Section 3.—In the table of chemical composition, change the requirements for Grade B bronze to read as follows by the addition of the italicized figures and the omission of those in brackets:

	GRADE B
Copper, per cent	[89.5] *88.25* - 90.5*0*
Aluminum, per cent	9.5*0* - 10.5*0*
Iron, per cent	1.25 max.
Tin, max., per cent	[0.2]
Total other impurities, max., per cent	0.5*0*

The committee recommends that the Standard Specifications for Sheet High Brass (B 36 - 33)[4] be revised and reissued in the form of new Tentative Specifications for Sheet and Strip Brasses, as appended hereto.[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 724 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 354.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 684 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 364.

[3] See Editorial Note, p. 228.

[4] 1936 Book of A.S.T.M. Standards, Part I, pp. 543, 620.

[5] See p. 693.

Adoption of Tentative Standards as Standard:

The committee recommends that the following two tentative specifications be approved for reference to letter ballot of the Society for adoption as standard:

Tentative Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 – 36 T),[1] and
Tentative Specifications for Car and Tender Journal Bearings, Lined (B 67 – 36 T).[1]

Withdrawal of Standard:

The committee recommends the withdrawal of the Standard Specifications for Yellow Brass Sand Castings for General Purposes (B 65 – 28).[2]

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. REVISIONS OF TENTATIVE STANDARDS			
Specifications for Wrought Phosphor Bronze Bearings and Expansion Plates for Bridges and Structures (B 100 – 35 T)	28	0	15
Specifications for Bronze Castings for Turntables and Movable Bridges (B 22 – 36 T):			
Section 1	26	0	17
Section 6	22	0	21
Specifications for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (B 111 – 37 T):			
Section 6 (*a*)	23	0	20
Section 7 (*b*)	21	0	22
II. REVISIONS OF STANDARDS			
Specifications for Aluminum-Bronze Castings (B 59 – 36), immediate adoption	28	0	15
Specifications for Sheet High Brass (B 36 – 33)	28	0	15
III. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 – 36 T)	26	0	17
Specifications for Car and Tender Journal Bearings, Lined (B 67 – 36 T)	24	0	19
IV. WITHDRAWAL OF STANDARD			
Standard Specifications for Yellow Brass Sand Castings for General Purposes (B 65 – 28)	29	0	14

Tentative Revisions Continued:

The committee recommends that the tentative revisions in the following standard specifications as presented last year be continued as tentative:

Standard Specifications for Manganese-Bronze Ingots for Sand Castings (B 7 – 27), and
Standard Specifications for Manganese-Bronze Sand Castings (B 54 – 27).

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 60 voting members; 43 members returned their ballots, the results being shown in Table I.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Wrought Metals and Alloys (R. A. Wilkins, chairman).—Experience in the use of the Tentative Specifications for Wrought Phosphor Bronze Bearings and Expansion Plates for Bridges and Structures (B 100 – 35 T), since they were first issued in 1935, have shown the desirability of making certain rather extensive changes which have been incorporated in the completely revised Tentative Specifications for Rolled Copper-Alloy Bearing and Expansion Plates for Bridges and Other Structural Uses, appended hereto.[3]

The subcommittee is also recommending revisions in the Tentative Specifications for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (B 111 – 37 T) as mentioned earlier in this report. The changes in these specifications will serve to clarify the requirements in Sections 6 (*a*) and 7 (*b*) which have proved to be ambiguous.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, pp. 728, 731 (1936); also 1937 Book of A.S.T.M. Tentative Standards, pp. 358, 361.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 559.

[3] See p. 689.

The subcommittee is also recommending that the Standard Specifications for Sheet High Brass (B 36 – 33) be revised and reissued in the form of new Tentative Specifications for Sheet and Strip Brasses, appended hereto.[1] These new specifications are the culmination of several years' work and will combine in a single document the requirements for various brass alloys manufactured in the form of sheet and strip.

In view of the reorganization of the committee, referred to later in this report, the work of Subcommittee I has been completed, but it is recommended that all specifications originally prepared by this subcommittee which have been standard more than five years without change be scrutinized by the new subcommittees with a view to making desirable revisions.

Subcommittee II on Cast Metals and Alloys (G. H. Clamer, chairman).—This subcommittee is recommending a revision in the Tentative Specifications for Bronze Castings for Turntables and Movable Bridges (B 22 – 36 T), as mentioned earlier in this report, which has been found desirable as a result of difficulties experienced in meeting the present requirements for minimum set of 0.06 in. in 1 in. under a load of 100,000 lb. per sq. in., with a deformation limit of 24,000 lb. per sq. in.

A revision is also being presented for immediate adoption in the Standard Specifications for Aluminum Bronze Castings (B 59 – 36). The Tentative Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 – 36 T), and for Car and Tender Journal Bearings, Lined (B 67 – 36 T), are being recommended for adoption as standard.

Subcommittee II is also recommending the withdrawal of the Standard Specifications for Yellow Brass Sand Castings for General Purposes (B 65 – 28) since these specifications are to be rewritten to include alloys Nos. 11, 12, 13, and 14, now listed in the Standard Specifications for Copper-Base Alloys in Ingot Form for Sand Castings (B 30 – 36).

The subcommittee proposes to consider the following items in its future program of work:

(*1*) The inclusion of physical properties in all castings specifications with the recommendation that they, rather than chemical composition, be considered the basic requirements. The latter, however, should be sufficiently complete to indicate the type of alloy.

(*2*) Addition to the Standard Specifications for Manganese-Bronze Ingots for Sand Castings (B 7 – 27), and for Manganese-Bronze Sand Castings (B 54 – 27) of requirements for two or more alloys of higher tensile strength and lower elongation in which manganese is used for deoxidization.

(*3*) While the Standard Specifications for Steam or Valve Bronze Castings (B 61 – 36), covering alloy No. 1 of the Standard Specifications for Copper-Base Alloys in Ingot Form for Sand Castings (B 30 – 36), will be continued as a specification covering an individual alloy as at present, since this alloy is used under high-temperature conditions, but it is proposed that alloys Nos. 2 and 3 of Specifications B 30 be covered in separate castings specifications to be prepared by the subcommittee.

(*4*) In order to simplify the preparation of specifications for the many copper-base casting alloys, some grouping of similar alloys seems desirable. As a possible A.S.T.M. recommended practice, the committee is considering the rather complete classification and nomenclature appearing in the 1938 Casting Manual—Non-Ferrous Metals, published by Metal Industry, New York City. The adoption of a classification of this nature would not prevent the use of names for individual alloys such as have acquired commercial value through use, but would facilitate the writing of specifications covering groups of alloys of somewhat similar composition.

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[1] See p. 693.

(*5*) It is recommended that castings specifications be prepared for the group of alloys corresponding to those listed in Specifications B 30 under the heading, "semi-red brass."

(*6*) It is also recommended that the Subcommittee on Cast Metals and Alloys review the need for specifications covering nickel containing copper-base alloys for foundry use similar in form to Specifications B 30.

(*7*) New specifications for yellow brass sand castings for general purposes will be prepared to replace the Standard Specifications B 65, which are recommended to be withdrawn, the new specifications to include castings corresponding to alloys Nos. 11, 12, 13, and 14 now covered in Specifications B 30.

Subcommittee II also recommended that Committee B-5 request the Joint Research Committee of the A.S.M.E. and A.S.T.M. on Effect of Temperature on the Properties of Metals to devote some of its efforts and funds to the investigation of some of the widely used copper-base alloys in service at elevated temperature; also that as many alloys be investigated as is possible under the present set-up or through other channels.

In accordance with new by-laws drawn up to cover the procedure of the committee, the subcommittees have been reorganized as follows:

I on Copper-Zinc Sheet and Strip (G. H. Harnden, chairman),
II on Copper-Tin Sheet and Strip (R. J. Wheeler, chairman),
III on Copper-Nickel-Zinc Sheet and Strip (E. S. Bunn, chairman),
IV on Miscellaneous Copper-Base Sheet and Strip Alloys (D. K. Crampton, chairman),
V on Miscellaneous Copper-Base Wire and Rod Alloys (W. H. Bassett, Jr., chairman),
VI on Condenser Tubes (G. C. Holder, chairman),
VII on Copper or Deoxidized Copper Tubes (O. Z. Klopsch, chairman),
VIII on Copper Alloy Tubes for General Use (Alan Morris, chairman),
IX on Copper-Base Alloy Forgings,
X on Copper-Base Alloys for Sand Castings (G. H. Clamer, chairman),
XI on Methods of Test for Copper and Copper Alloys, and
XII on Publication of General Information (C. S. Cole, chairman).

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents. In addition, two vice-chairmen, J. W. Bolton of the Lunkenheimer Co., and H. H. Stout, Jr., of the Phelps Dodge Copper Products Corp., were unanimously elected as first and second vice-chairman, respectively, for the ensuing term of two years.

This report has been submitted to letter ballot of the committee which consists of 60 voting members; 43 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

C. H. GREENALL,
Chairman.

C. H. DAVIS,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee B-5 on Copper and Copper Alloys, Cast and Wrought, presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Revision of Tentative Specifications for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (B 111 – 38 T),

Proposed Tentative Revision of Standard Specifications for Aluminum-Bronze Castings (B 59 – 38).

These recommendations were accepted by Committee E-10 and appear on pp. **702** and **1319**, respectively.

REPORT OF COMMITTEE B-6
ON
DIE-CAST METALS AND ALLOYS

Committee B-6 on Die-Cast Metals and Alloys has held two meetings during the year, one in New York City on July 1, 1937, and one in Rochester, N. Y., on March 10, 1938, with an attendance at the two meetings of 28 and 33, respectively. The subcommittees have also held meetings at various times during the year.

The following additions and changes in membership have been approved:

E. N. Jacobi, Briggs & Stratton Corp.,
E. H. Kelton, The New Jersey Zinc Co.,
Leopold Pessel, Mutual Chemical Co. of America,
B. E. Sandell, Stewart Die Casting Corp.,
D. Basch replacing J. A. Capp, deceased, National Electrical Manufacturers Assn.,
T. S. Fuller replacing J. A. Capp, deceased, General Electric Co.,
C. E. Macfarlane replacing H. C. Loudenbeck, Westinghouse Air Brake Co.,
C. T. Prendergast replacing H. A. Anderson, Western Electric Co., Inc.

At the present time the committee consists of 62 members, of whom 26 are classified as producers, 20 as consumers, and 16 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

Revision of Tentative Standard:

The committee recommends that the Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 – 34 T)[1] be revised as follows and continued as tentative:

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 1. These specifications cover commercial die castings, die cast from zinc-base alloys. [Two] *Three* alloy compositions are specified, designated alloys Nos. XXI, [and] XXIII *and XXV*.

Section 4.—Add to the table of chemical composition, requirements for alloy No. XXV to read as follows:

	ALLOY No. XXV
Copper, per cent............	0.75 to 1.25
Aluminum, per cent..........	3.5 to 4.3
Magnesium, per cent.........	0.02 to 0.08
Iron, max., per cent.........	0.100
Lead, max., per cent.........	0.007
Cadmium, max., per cent.....	0.005
Tin, max., per cent..........	0.002
Zinc, per cent...............	remainder

Section 6.—Add to the requirements of this section a column for alloy No. XXV with the maximum expansion of 0.0010 in. per in.

Section 8.—Add to the table of physical properties, requirements for alloy No. XXV to read as follows, changing the heading of the column "Average of five specimens" to read "Average of specimens (see Section 11)":

	AVERAGE OF SPECIMENS (see Section 11) ALLOY No. XXV	INDIVIDUAL SPECIMENS ALLOY No. XXV
Tensile strength, min., lb. per sq. in.	40 000	32 000
Elongation in 2 in., min., per cent....	2.0	0.5
Charpy impact, min., ft-lb........	12.0	8.0

Figure 2.—Change the caption of this figure from "Charpy Impact Test Specimen" to read "Test Bar from Which Two Charpy Impact Test Specimens are Cut."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 706 (1934); also 1937 Book of A.S.T.M. Tentative Standards, p. 424.

Section 9.—Add to the table of physical properties required after exposure to water vapor at 95 C. for 10 days, requirements for alloy No. XXV to read as follows, changing the heading of the column "Average of five specimens" to read "Average of specimens (see Section 11)":

	AVERAGE OF SPECIMENS (see Section 11) ALLOY NO. XXV
Tensile strength, min., lb. per sq. in.	30 000
Elongation in 2 in., min., per cent.	1.0
Charpy impact, min., ft-lb. . .	6.0

Section 11.—Change this section from its present form: namely,

> 11. Five of each type of test specimen shall be tested.

to read as follows:

> 11. Five tension specimens and 10 impact specimens (cut from 5 bars) shall be tested.

This recommendation has been submitted to letter ballot of the committee, which consists of 62 members; 41 members returned their ballots, of whom 35 have voted affirmatively, 2 negatively, and 4 members marked their ballots "not voting."

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Aluminum-Base Die-Casting Alloys (E. E. Thum, chairman).—This subcommittee has appointed a special subgroup consisting of D. L. Colwell and H. A. Anderson to investigate the effect of impurities on aluminum-base alloy die castings.

Aluminum die-cast alloy test specimens of higher than commercial purity have also been placed on the exposure test racks. As yet no test data are available from these exposure tests.

Subcommittee II on Zinc-Base Die-Casting Alloys (C. E. Heussner, chairman).—This subcommittee is recommending a revision of the Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 - 34 T), as mentioned earlier in this report, to include composition requirements and data on the physical properties of alloy No. XXV.

Subcommittee III on Tin- and Lead-Base Die-Casting Alloys (G. O. Hiers, chairman).—The plans of this subcommittee for an investigation of tin- and lead-base die-casting alloys to determine their physical properties have been delayed by the inability of the subcommittee to obtain a second set of specimens for test. It has been decided to make tension tests and creep tests on the specimens already submitted. There is still some question as to the value of impact and hardness tests. It is hoped that the additional test specimens will be made available in the near future so that these studies may be undertaken without further delay.

Subcommittee IV on Physical Tests of Die Castings (R. L. Templin, chairman).—This subcommittee is recommending to the subcommittees the addition to the four tentative specifications for die castings of a statement that tension tests shall be made at a free-running, testing machine head speed of approximately $\frac{1}{4}$ in. per min. and that the test shall be carried out at ordinary room temperature.

The subcommittee is also recommending to the subcommittees that a note covering the use of tension test data for engineering design be added to all die-casting specifications except the Specifications for Lead- and Tin-Base Die Castings (B 102 - 35 T).

Subcommittee V on Exposure and Corrosion Tests (W. M. Peirce, chairman).—This subcommittee has reported that it has been necessary to postpone the exposure test programs because die casters who had agreed to supply the necessary test specimens were too busy to produce the specimens required. These die casters are now being canvassed to determine whether or not the program can be carried out during the summer of 1938. This subcommittee also offered the services of G. L. Werley to the producers of test bars for these exposure tests to insure reproducibility of results on test specimens when the recommended die practices described last year[1] by Mr. Werley in the report of Committee B-6 are followed using other machines. Mr. Werley will be available to examine test bars with gates attached and will offer suggestions as to modifications which might better adapt the recommended practices to individual die-casting machines. Committee B-6 authorized Subcommittee V to include in the corrosion exposure studies, specimens of magnesium-base alloys Nos. 307, 312, 313 and 314, having the following compositions:

	ALLOY No. 307	ALLOY No. 312	ALLOY No. 313	ALLOY No. 314
Aluminum, per cent	6.0 to 7.0	9.5 to 10.5	8.5 to 9.5	6.0 to 7.0
Silicon, max., per cent	0.5	1.0	0.1	0.5
Manganese, min., per cent	0.15	0.1	0.1	0.15
Zinc, per cent	...	...	0.4 to 0.8	2.0 to 3.0
Magnesium, per cent	remainder	remainder	remainder	remainder

Subcommittee VI on Finishing Properties of Die Castings (J. C. Fox, chairman).—The work on finishes carried out by the Joint Committee on Exposure Tests of Plating on Non-Ferrous Metals, made up of representatives of the American Electro-Platers' Society, the National Bureau of Standards, and the A.S.T.M., is being continued.

Subcommittee VII on Magnesium-Base Die-Casting Alloys (J. A. Gann, chairman).—This subcommittee is considering two new magnesium-base die-casting alloys. When their merits are established a report will be submitted.

A balance of $207.44 is reported by Society headquarters in the fund of Committee B-6.

The nominating committee consisting of W. H. Finkeldey, W. M. Peirce, and P. V. Faragher was appointed and approved by the Advisory Committee to present nominees for chairman, vice-chairman, and secretary at the June, 1938, meeting.

The election of officers for the ensuing term of two years resulted in the re-election of the present chairman and the election of J. C. Fox, vice-chairman, and G. L. Werley, secretary.

Committee B-6 unanimously extends to H. A. Anderson a vote of appreciation for his interest and services in advancing the work of Committee B-6 from its organization as a subcommittee of Committee B-2 to its subsequent reorganization as a separate standing committee of the Society.

This report has been submitted to letter ballot of the committee, which consists of 62 members; 41 members returned their ballots, of whom 39 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

J. R. TOWNSEND,
Chairman.

P. V. FARAGHER,
Secretary.

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[1] G. L. Werley, "A Study of Die Design Changes for the Improvement of the Soundness and Uniformity of Test Bars," *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 223 (1937).

REPORT OF COMMITTEE B-7
ON
LIGHT METALS AND ALLOYS, CAST AND WROUGHT

Committee B-7 on Light Metals and Alloys, Cast and Wrought, has held two meetings during the year: one in New York City on July 1, 1937, and the other in Rochester, N. Y., on March 10, 1938.

Since the 1937 annual meeting, Committee B-7 has lost 2 members, and 6 new members have been added to the committee, making a net increase of 4 members; three other members have been replaced by new company representatives. The membership of the committee now totals 46, of whom 21 are classified as producers, 15 as consumers, and 10 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

The committee recommends that the Tentative Method of Test for Dielectric Strength of Anodized Aluminum which has been prepared in response to requests from the light metals industry, be accepted for publication as tentative, as appended hereto.[1]

The new tentative method is based on the data in the Report on Methods of Testing Oxide Coatings on Aluminum, submitted with the annual report of Committee B-7 in 1937.[2] When the purpose of the measurement is to determine the minimum break-down voltage of the coating at any point, the use of a flat electrode may be advantageous, as noted in the 1937 report of the committee. However, a flat electrode has several real disadvantages for general use, since its application is limited to flat surfaces, and unless intimate surface contact is obtained, spurious effects due to small entrapped air pockets are liable to result. Since, however, one of the principal uses of this method at the present time is to obtain an approximate measure of the thickness of anodic coatings, the use of a conical electrode with a spherical apex of such a size that the contact pressure will be of minimum significance has been specified as being best adapted for this application. This method can be readily employed for manufacturing control work by determining the approximate break-down voltage of a satisfactory coating and then ascertaining whether any particular coating has a break-down voltage above or below this predetermined limit.

Revisions of Tentative Standards:

The committee recommends that the following nine tentative specifications be revised, as given in detail in Appendix I, and continued as tentative:

Tentative Specifications for:

Magnesium-Base Alloy Sand Castings (B 80 – 36 T),
Magnesium-Base Alloy Sheet (B 90 – 36 T),
Magnesium-Base Alloy Forgings (B 91 – 36 T),
Magnesium-Base Alloy Bars, Rods, and Shapes (B 107 – 36 T),
Magnesium-Base Alloy Ingot for Remelting (B 93 – 36 T),

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[1] See p. 652.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 261 (1937).

- Aluminum-Base Alloys in Ingot Form for Permanent Mold Castings (B 112 – 37 T),
- Aluminum-Manganese Alloy Sheet and Plate (B 79 – 36 T),
- Aluminum Sheet and Plate (B 25 – 36 T), and
- Aluminum-Base Alloy Permanent Mold Castings (B 108 – 37 T).

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 46 members; 36 members returned their ballots, the results being given in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Method of Test for Dielectric Strength of Anodized Aluminum	23	0	13
II. REVISIONS OF TENTATIVE STANDARDS			
Magnesium-Base Alloy Sand Castings (B 80 – 36 T)	23	0	13
Magnesium-Base Alloy Sheet (B 90 – 36 T)	24	0	12
Magnesium-Base Alloy Forgings (B 91 – 36 T)	23	0	13
Magnesium-Base Alloy Bars, Rods, and Shapes (B 107 – 36 T)	23	0	13
Magnesium-Base Alloy Ingot for Remelting (B 93 – 36 T)	23	0	13
Aluminum-Base Alloys in Ingot Form for Permanent Mold Castings (B 112 – 37 T)	29	0	7
Aluminum-Manganese Alloy Sheet and Plate (B 79 – 36 T)	25	0	11
Aluminum Sheet and Plate (B 25 – 36 T)	23	0	13
Aluminum-Base Alloy Permanent Mold Castings (B 108 – 37 T)	29	0	7

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Aluminum and Aluminum Alloy Ingots (D. L. Colwell, chairman).—This subcommittee recommends the revision of the Tentative Specifications for Aluminum-Base Alloys in Ingot Form for Permanent Mold Castings (B 112 – 37 T) as given in detail in Appendix I. It is also preparing specifications for aluminum-base alloys in ingot form for die castings, and is working on a revision of the Standard Specifications for Aluminum Ingots for Remelting (B 24 – 29). Plans are being made for the revision of The Standard Specifications for Aluminum for Use in the Manufacture of Iron and Steel (B 37 – 26) in cooperation with the interested standing committees of the Society having jurisdiction over specifications for iron and steel.

Subcommittee II on Aluminum Alloy Castings (C. H. Greenall, chairman).—This subcommittee has prepared a revision of the Tentative Specifications for Aluminum-Base Alloy Permanent Mold Castings (B 108 – 37 T), as given in Appendix I. The subcommittee is also making an extensive study of the effect of impurity variations on the properties of aluminum-base alloys.

Subcommittee III on Aluminum Alloy Wrought Shapes (P. V. Faragher, chairman).—In order to incorporate minimum tensile strength requirements covering annealed plate, which have been indicated as necessary for the purpose of design in boiler and pressure vessel construction, this subcommittee is presenting revisions of the Tentative Specifications for Aluminum-Manganese Alloy Sheet and Plate (B 79 – 36 T) and for Aluminum Sheet and Plate (B 25 – 36 T), as given in detail in Appendix I.

Subcommittee IV on Magnesium and Magnesium Alloys, Cast and Wrought (J. A. Gann, chairman).—This subcommittee has prepared revisions of five tentative specifications under its jurisdiction. The Tentative Specifications for Magnesium-Base Alloy Sand Castings (B 80 – 36 T) are being revised by the deletion of alloys Nos. 1 and 5 and the addition of alloy No. 14 which has physical properties very similar to those of alloy No. 3 but with salt-water corrosion resistance and heat treating characteristics that are somewhat better. The Tentative Specifications for Magnesium-Base Alloy Sheet (B 90 – 36 T) are to be amplified by the addition of alloy No. 7 which has desirable physical properties and approaches the formability of sheet alloy No. 6.

The Tentative Specifications for Magnesium-Base Alloy Forgings (B 91 – 36 T) are being revised by the deletion of alloys Nos. 7 and 10, little used today, and the addition of two new alloys Nos. 15 and 16. Alloy No. 15 has good press-forging characteristics and offers better corrosion resistance than some of the other alloys. Alloy No. 16 is the best hammer-forging magnesium alloy having physical properties about the same as alloy No. 6, but its salt-water corrosion resistance is distinctly better. Alloy No. 15 will also be incorporated in the Tentative Specifications for Magnesium-Base Alloy Bars, Rods, and Shapes (B 107 – 36 T). This alloy possesses an excellent combination of physical properties and salt-water corrosion resistance and it can be heat treated and aged, in which condition its yield strength is equal to that of the other alloys.

In the Tentative Specifications for Magnesium-Base Alloy Ingot for Remelting (B 93 – 36 T) a forging and a casting alloy are being deleted and three new alloys are being added: namely, one for casting, one used for press forging and for bars, rods, and shapes, and a third for hammered forgings. These revisions are given in detail in Appendix I.

Subcommittee V on Testing Light Metals (R. L. Templin, chairman).—This subcommittee is following with interest the work of the Section on Effect of Speed of Testing of Committee E-1 on Methods of Testing, and plans to suggest at least one aluminum and at least one magnesium-base alloy to be included in the investigations of that committee. Subcommittee V is presenting a report prepared by H. J. Rowe on "The Effect of Foundry Variables on the Mechanical Properties of Sand-Cast Tension Test Specimens," which appears in Appendix II.

Subcommittee VI on Anodic Oxidation of Aluminum and Aluminum Alloys (T. S. Fuller, chairman).—This subcommittee has prepared a proposed Tentative Method of Test for Dielectric Strength of Anodized Aluminum, as appended hereto.[1] Subcommittee VI has under consideration the development of tentative methods of conducting abrasion and sealing tests on anodized aluminum coatings, and also the preparation of a report on the applicability of anodizing as applied to different aluminum alloys.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, Sam Tour.
Vice-Chairman, J. A. Gann.
Secretary, H. J. Rowe.

This report has been submitted to letter ballot of the committee which consists of 46 members; 36 members returned their ballots, of whom 34 have voted affirmatively and 2 negatively.

Respectfully submitted on behalf of the committee,

SAM TOUR,
Chairman.

J. A. GANN,
Secretary.

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[1] See p. 652.

APPENDIX I

PROPOSED REVISIONS IN STANDARDS FOR LIGHT METALS AND ALLOYS

In this Appendix are given proposed revisions in certain tentative standards covering light metals and alloys, cast and wrought, which are referred to earlier in this report. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

Tentative Specifications for Magnesium-Base Alloy Sand Castings (B 80 – 36 T):[1]

Section 1.—Change the last sentence to read as follows by the addition of the italicized word and figure and the omission of the figures in brackets:

> [Five] *Four* alloys are specified and are designated Alloys Nos. [1,] 2, 3, 4, and [5] *14* (see Explanatory Note 1).

Section 3.—In the table of chemical composition omit the requirements for Alloys Nos. 1 and 5, and add alloy No. 14 having the following composition:

Magnesium, per cent	remainder
Aluminum, per cent	9.0 to 11.0
Manganese, min., per cent	0.10
Zinc, per cent	0.5 to 1.5
Copper, max., per cent	0.05
Silicon, max., per cent	0.5
Other impurities,[a] max., per cent	0.3

[a] Nickel, max., 0.03 per cent.

TABLE I.

Alloy	Condition	Tensile Strength, min., lb. per sq. in.	Elongation in 2 in., min., per cent
No. 2	Heat treated and aged	29 000	not required
No. 3	Heat treated and aged	27 000	not required
No. 4	As-cast	24 000	4
	Heat treated	30 000	6
	Heat treated and aged	32 000	2
No. 14	Heat treated and aged	30 000	not required

TABLE II.

Alloy	Condition	Typical Yield Strength (Offset = 0.2 per cent), lb. per sq. in.	Unit Deformation, in. per in. of gage length
No. 2	Heat treated and aged	19 000	0.0049
No. 3	Heat treated and aged	21 000	0.0052
No. 4	As-cast	11 000	0.0037
	Heat treated	11 000	0.0074
	Heat treated and aged	19 000	0.0098
No. 14	Heat treated and aged	22 000	0.0054

Section 5.—Change the table of tensile properties from its present form to read as shown in Table I.

Explanatory Notes.—In Note 1 omit the paragraphs referring to Alloys Nos. 1 and 5.

At the end of Note 1 add a new paragraph covering Alloy No. 14, to read as follows:

> *Alloy No. 14.*—This alloy has a specific gravity of about 1.82. It is used in the solution-heat-treated and aged condition for castings requiring the maximum obtainable yield strength. Its physical properties are very similar to those of Alloy No. 3 but its

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 708 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 342.

salt-water corrosion-resistance and heat-treating characteristics are somewhat better. The copper and nickel contents should be kept low to minimize corrosion.

In Note 2 change the table of data from its present form to read as shown in Table II.

Tentative Specifications for Magnesium-Base Alloy Sheet (B 90 - 36 T):[1]

Section 1.—Change the last sentence to read as follows by the addition of the italicized word and figure and the omission of the word in brackets:

[Two] *Three* alloys are specified and are designated Alloys Nos. 6, *7,* and 11 (see Explanatory Note 1).

Section 3.—Add to the table of chemical requirements, Alloy No. 7 having the following composition:

Magnesium, per cent	remainder
Aluminum, per cent	5.8 to 7.2
Manganese, min., per cent	0.15
Copper, max., per cent	0.05
Zinc, max., per cent	0.3
Silicon, max., per cent	0.5
Other impurities,[a] max., per cent	0.3

[a] Nickel, max., 0.03 per cent.

Section 5.—To the table of tensile properties add the requirements for Alloy No. 7 as shown in Table III.

Explanatory Notes.—Add as the second paragraph of Note 1, a new paragraph referring to Alloy No.7, to read as follows:

Alloy No. 7.—This alloy has a specific gravity of about 1.79. Its physical properties are superior to Alloy No. 6 while its forming characteristics approach those of Alloy No. 6. The copper and nickel contents should be kept low to minimize corrosion.

Add to the table in Note 2, Alloy No. 7 having a minimum yield strength of 28,000 lb. per sq. in. and a unit deformation of 0.0063 in. per in. of gage length.

TABLE III.

ALLOY	CONDITION	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
No. 7	Hard rolled (H)	39 000 min.	28 000	3
	Annealed (A)	42 000 max.	......	10

TABLE IV.

	ALLOY NO. 15	ALLOY NO. 16
Magnesium, per cent	remainder	remainder
Aluminum, per cent	2.5 to 3.5	3.0 to 4.0
Manganese, min., per cent	0.20	0.20
Zinc, per cent	2.5 to 3.5	0.3 max.
Copper, max., per cent	0.05	0.05
Tin, per cent	.....	4.0 to 6.0
Silicon, max., per cent	0.5	0.5
Other impurities,[a] max., per cent	0.3	0.3

[a] Nickel, max., 0.03 per cent.

TABLE V.

ALLOY	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
No. 15	38 000	20 000	9.0
No. 15A (aged)	38 000	22 000	7.0
No. 16	35 000	20 000	6.0

Tentative Specifications for Magnesium-Base Alloy Forgings (B 91 - 36 T):[2]

Section 1.—Change the last sentence to read as follows by the addition of the italicized word and figures and the omission of the word and figures in brackets:

Six alloys are specified and are designated Alloys Nos. 1, 6, [7,] 8, 9, [and 10] *15, and 16* (see Explanatory Note 2).

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 712 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 346.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 716 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 334.

Section 3.—In the table of chemical composition omit the requirements for Alloys Nos. 7 and 10, and add Alloys Nos. 15 and 16 having the compositions shown in Table IV.

Section 5.—In the table of tensile properties omit the requirements for Alloys Nos. 7 and 10, and add Alloys Nos. 15 and 16 having the properties shown in Table V.

Explanatory Notes.—In Note 2 omit the paragraphs referring to Alloys Nos. 7 and 10.

TABLE VI.

ALLOY	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	UNIT DEFORMATION, IN PER IN. OF GAGE LENGTH
No. 15	20 000	0.0051
No. 15A (aged)	22 000	0.0054
No. 16	20 000	0.0051

TABLE VII.

ALLOY	SHAPE AND SIZE	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
No. 15	Round and Square up to 1½ in	39 000	26 000	15
	Structural shapes	39 000	22 000	10
No. 15A	Round and Square up to 1½ in	41 000	30 000	10
	Structural shapes	40 000	25 000	8

TABLE VIII.

ALLOY	SHAPE AND SIZE	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	UNIT DEFORMATION, IN PER IN. OF GAGE LENGTH
No. 15	Round and Square up to 1½ in	26 000	0.0060
	Structural shapes	22 000	0.0054
No. 15A	Round and Square up to 1½ in. (aged)	30 000	0.0066
	Structural shapes (aged)	25 000	0.0058

At the end of Note 2 add two new paragraphs referring to Alloys Nos. 15 and 16, to read as follows:

> *Alloy No. 15.*—This alloy has a specific gravity of about 1.80. It has good press-forging characteristics and a greater resistance to salt water corrosion than Alloys Nos. 1, 6, 8, and 9. Forgings may be heat treated and aged to improve the yield strength. The copper and nickel contents should be kept low to minimize corrosion.
>
> *Alloy No. 16.*—This alloy has a specific gravity of about 1.87. It is the best alloy for hammer forging. Its physical properties are about the same as Alloy No. 6 but its salt-water corrosion-resistance and forging characteristics are distinctly better. The copper and nickel contents should be kept low to minimize corrosion.

In the table in Note 3 omit Alloys Nos. 7 and 10 and add Alloys Nos. 15 and 16 having the characteristics shown in Table VI.

Tentative Specifications for Magnesium-Base Alloy Bars, Rods, and Shapes (B 107 - 36 T):[1]

Section 1.—Change the last sentence to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

> [Four] *Five* alloys are specified and are designated Alloys Nos. 6, 8, 9, [and] 11, *and 15* (see Explanatory Note 1).

Section 3.—Add to the table of chemical requirements, Alloy No. 15 having the following composition:

Magnesium, per cent	remainder
Aluminum, per cent	2.5 to 3.5
Manganese, min., per cent	0.20
Zinc, per cent	2.5 to 3.5
Copper, max., per cent	0.05
Silicon, max., per cent	0.5
Other impurities,[a] max., per cent	0.3

[a] Nickel, max., 0.03 per cent.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 720 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 330.

Section 5.—Add to the table of tensile properties requirements for Alloy No. 15 having the properties shown inTable VII.

Explanatory Notes.—At the end of Note 1 add a new paragraph referring to Alloy No. 15, to read as follows:

> *Alloy No. 15.*—This alloy has a specific gravity of about 1.80. It possesses an excellent combination of high physical properties and good resistance to salt water. Its resistance to salt-water corrosion is superior to that of Alloys Nos. 6, 8, and 9 and in the aged condition (No. 15A) its yield strength is equal to that of any of the other alloys while it is easier to extrude than Alloy No. 9.

Add to the table in Note 3, Alloy No. 15 having the characteristics shown in Table VIII.

TABLE IX.

	ALLOY NO. 14	ALLOY NO. 15	ALLOY NO. 16
Magnesium, per cent	remainder	remainder	remainder
Aluminum, per cent	9.4 to 10.6	2.7 to 3.3	3.2 to 3.8
Manganese, min., per cent	0.13	0.25	0.25
Zinc, per cent	0.7 to 1.3	2.7 to 3.3	....
Copper, max., per cent	0.04	0.04	0.04
Tin, per cent	....	....	4.3 to 5.7
Silicon, max., per cent	0.2	0.2	0.2
Other impurities,[a] max., per cent	0.3	0.3	0.3

[a] Nickel, max., 0.02 per cent.

Tentative Specifications for Magnesium-Base Alloy Ingot for Remelting (B 93 - 36 T):[1]

Section 1.—Change the last sentence to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> [Twelve] *Thirteen* alloys are specified and are designated Alloys Nos. [1 to 12, inclusive] *1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 14, 15, and 16* (Note 2).

Section 3.—In the table of chemical composition omit the requirements for Alloys Nos. 5 and 10, and add Alloys Nos. 14, 15, and 16 having the compositions shown in Table IX.

Tentative Specifications for Aluminum-Base Alloys in Ingot Form for Permanent Mold Castings (B 112 - 37 T):

Table I.—Change Note 4 to read as follows by the addition of the italicized figures:

> NOTE 4.—Titanium is permissible in Alloys *1A, 2*, 3, 4, *5*, 9, 9A, and 10 but the maximum shall not exceed 0.2 per cent.

In the table change the silicon content of Alloy No. 2 from "3.0 ± 0.8 per cent" to read "4.0 per cent max."

Section 8 (b).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> (*b*) If the purchaser elects to have inspection made at the manufacturer's works, [the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the manufacture of the material ordered.] the manufacturer shall afford the inspector *representing the purchaser* [without charge] all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Section 10.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 10. In the case of dissatisfaction regarding rejections based on quality or chemical composition requirements *as* specified in Sections 3 and 4, *respectively*, the manufacturer may make claim for [a] rehearing as [the] *a* basis of arbitration within [five working days or *15 calendar days after* receipt by the manufacturer of the rejection notification.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 706 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 340.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 671 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 293.

Tentative Specifications for Aluminum-Manganese Alloy Sheet and Plate (B 79 - 36 T):[1]

Section 2.—Change from its present form: namely,

2. No scrap shall be used in the manufacture of aluminum-manganese alloy sheet and plate except such as shall accumulate at the manufacturer's plants from material of similar composition and of his own manufacture.

to read as follows:

2. The materials used for the production of aluminum-manganese alloy sheet and plate shall be such as to produce products which comply with the physical and chemical properties prescribed in these specifications.

Section 3.—Change the table of chemical composition from its present form: namely,

Aluminum, minimum, per cent....	97.0
Manganese, per cent.............	1.0 to 1.5
Copper, maximum, per cent.......	0.2

to read as follows:

Manganese, per cent.............		1.0 to 1.5
Iron, max., per cent.............		0.7
Copper, max., per cent...........		0.2
Silicon, max., per cent...........		0.6
Other elements	each, max., per cent..	0.03
	total, max., per cent..	0.10
Aluminum, per cent.............		remainder

NOTE.—Analysis shall regularly be made only for the elements specified in Section 3. If in the course of routine analysis the presence of other elements is indicated, analysis shall be made to determine the amount of each which is present.

Section 5.—Change Paragraphs (*b*) and (*c*) from their present form: namely,

(*b*) Unless otherwise specified, plate (thicknesses 0.250 in. and over) shall be supplied as rolled (see Explanatory Note 2) and tension tests shall not be required.

(*c*) If so specified, plate shall be supplied in the soft temper in thicknesses from 0.250 to 3.000 in., in which case the tensile strength shall not exceed 19,000 lb. per sq. in. and the elongation shall not be less than 25 per cent in 2 in.

to read as follows:

(*b*) Unless otherwise specified, plate (thicknesses 0.250 in. and over) shall be supplied as rolled. Mechanical property tests of as-rolled plate are not required except when specifically required by the order or contract. When so specified in the contract or order, plate shall conform to the following requirements:

THICKNESS, IN.	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
0.250 to 0.625....	17 000	8
0.626 to 2.000....	15 500	8
2.001 to 3.000....	as agreed upon between the purchaser and the seller	..

(*c*) If so specified in the contract or order, plate shall be annealed. Annealed plate shall have a tensile strength not less than 14,000 lb. per sq. in. and not more than 21,000 lb. per sq. in., and the elongation shall not be less than 18 per cent in 2 in.

Section 6.—Change Paragraph (*a*) to to read as follows by the addition of the italicized words and the omission of those in brackets:

6. (*a*) Bend test specimens taken from sheet in the soft [or in the half-hard temper or from plate in the soft temper or "as rolled"] *temper and from annealed plate* shall stand being bent cold through 180 deg. flat on themselves without cracking.

Add a new paragraph as Paragraph (*b*) to read as follows, lettering the present Paragraphs (*b*) and (*c*) as (*c*) and (*d*), respectively:

(*b*) Bend test specimens taken from sheet in the half-hard temper in thicknesses up to $\frac{1}{8}$ in., inclusive, shall withstand being bent cold through 180 deg. flat on themselves. Bend test specimens taken from sheet thicker than $\frac{1}{8}$ in. in the half-hard temper, and from as-rolled plate shall stand being bent cold through 180 deg. around a pin having a diameter equal to two times the thickness of the specimen without cracking.

Section 10.—Add a sentence at the end of this section covering workmanship and finish, to read as follows:

They shall be supplied to the dimensions specified within the limits of good commercial practice.

Section 12.—Add a sentence at the end of this section covering rejection, to read as follows:

In case of rejection, the seller's responsibility shall be limited to replacing the material with other material which conforms to the requirements of these specifications, without charge to the purchaser.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 694 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 320.

Tentative Specifications for Aluminum Sheet and Plate (B 25 – 36 T):[1]

Section 2.—Change from its present form: namely,

2. No scrap shall be used in the manufacture of aluminum sheet and plate, except such as shall accumulate at the manufacturer's plants from material of similar composition and of his own manufacture.

to read as follows:

2. The materials used for the production of aluminum sheet and plate shall be such as to produce products which comply with the physical and chemical properties prescribed in these specifications.

Section 3.—Change from its present form: namely,

3. The sheet and plate shall contain a minimum of 99 per cent aluminum as determined by chemical analysis.

to read as follows:

3. The sheet and plate shall conform to the following requirements as to chemical composition:

Iron plus silicon, max., per cent	1.0
Copper, max., per cent	0.2
Manganese, max., per cent	0.05
Other impurities: each, max., per cent	0.03
Other impurities: total, max., per cent	0.10
Aluminum, per cent	remainder

NOTE.—Analysis shall regularly be made only for the elements mentioned in Section 3. If in the course of routine analysis, the presence of other elements is indicated, analysis shall be made to determine the amount of each which is present.

Section 5.—Change Paragraphs (*b*) and (*c*) from their present forms: namely,

(*b*) Unless otherwise specified, plate (thicknesses 0.250 in. and over) shall be supplied as rolled (see Explanatory Note 2) and tension tests shall not be required.

(*c*) If so specified, plate shall be supplied in the soft temper in thicknesses from 0.250 to 3.000 in., in which case the tensile strength shall not exceed 19,000 lb. per sq. in. and the elongation shall not be less than 25 per cent in 2 in.

to read as follows:

(*b*) Unless otherwise specified, plate (thicknesses 0.250 in. and over) shall be supplied as rolled. Mechanical property tests of as-rolled plate are not required except when specifically required by the order or contract. When so specified in the contract or order, plate shall conform to the following requirements:

Thickness, in.	Tensile Strength, min., lb. per sq. in.	Elongation in 2 in., min., per cent
0.250 to 0.625	13 000	9
0.626 to 2.000	12 000	9
0.201 to 3.000	as agreed upon between the purchaser and the seller	..

(*c*) If so specified in the contract or order, plate shall be annealed. Annealed plate shall have a tensile strength not less than 11,000 lb. per sq. in. and not more than 15,500 lb. per sq. in., and the elongation in 2 in. shall not be less than 28 per cent.

Section 10.—Add a sentence at the end of this section on workmanship and finish, to read as follows:

They shall be supplied to the dimensions specified within the limits of good commercial practice.

Section 12.—Add a sentence at the end of this section covering rejection, to read as follows:

In case of rejection, the seller's responsibility shall be limited to replacing the material with other material which conforms to the requirements of these specifications, without charge to the purchaser.

Tentative Specifications for Aluminum-Base Alloy Permanent Mold Castings (B 108 – 37 T):[2]

Section 5 (*a*).—Change to read as follows by the addition of the italicized words:

5. (*a*) The samples for chemical analyses shall be selected as far as possible by heats or melts, *or groups of heats or melts*, unless otherwise mutually agreed upon by the manufacturer and the purchaser.

Table I.—Change Note 4 to read as follows by the addition of the italicized figures:

NOTE 4.—Titanium is permissible in Alloys Nos. *1A*, *2*, 3, 4, *5*, 9, 9A, and 10 but the maximum shall not exceed 0.2 per cent.

In the table change the silicon content of Alloy No. 2 from "3.0 ± 1.0 per cent" to read "4.0 per cent, max."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 685 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 311.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 674 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 296.

Appendix.—In the Table of Supplementary Data make the following changes:

Alloy No. 1.—Under the column on machinability change "Good" to read "Excellent."

Alloy No. 4.—Under the column on principal use change "Automotive pistons" to read "Pistons and castings requiring high Brinell hardness."

Alloys Nos. 8, 9, 9A.—Under the column on machinability change "Poor" to read "Fair."

Alloy No. 10.—Change the approximate specific gravity from "2.70" to read "2.65."

APPENDIX II

THE EFFECT OF FOUNDRY VARIABLES ON THE MECHANICAL PROPERTIES OF SAND-CAST TENSION TEST SPECIMENS

By H. J. Rowe[1]

The popularity of the tension test as a means for production control is well deserved. The validity of the data obtained from this test is, however, dependent upon strict control and uniformity of conditions surrounding the making of the tension test specimens themselves.

It is the purpose of this discussion to attempt to clarify and summarize the effects of various foundry variables on the mechanical properties of tension specimens cast in aluminum alloys. The variables discussed are those encountered in molding practice, gating design, melting and pouring technique, and in the handling of test specimens during trimming and heat treating. The effect of machining the gage sections of test specimens is also considered.

It is realized that the data presented are far from complete in so far as the numerical effect of each variable on the properties of all the aluminum alloys is concerned. Sufficient data have been obtained, however, to indicate the general effects of these variables and the control necessary for maximum uniformity.

The alloys for which the data presented in the following discussion were obtained are covered by A.S.T.M. Tentative Specifications B 26 - 37 T[2] (see Table I for nominal chemical and mechanical properties). Much of the experimental work was carried out on alloy G since this alloy reflects well the variations in foundry conditions.

Molding Practice

Sand Permeability.—One of the most important factors in molding considerations is sand permeability. Upon this factor depends the rapidity with which gases, including steam, which may form an insulating film between the metal and green sand mold, are dispersed. If these gases, which of course develop from the moisture in the sand, escape rapidly through the mold, the metal achieves more intimate contact with the sand and hence is chilled more rapidly than when a gas film is maintained for a longer period.

Table I.—Sand-Cast Aluminum Alloys Included in Tests.

A.S.T.M. Alloy	Nominal Chemical Composition, per cent						Typical Mechanical Properties	
	Copper	Iron	Silicon	Zinc	Magnesium	Nickel	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent
Grade C...	7.0	1.2	2.0	2.0	...	...	23 000	1.5
Grade G[a]..	4.5	...	...	...	...	...	31 000	8.5
Grade H[b]..	4.0	...	...	...	1.5	2.0	37 000	0.5
Grade JJ...	...	...	5.0	...	...	...	19 000	6.0
Grade L...	...	...	...	...	3.8	...	25 000	9.0
Grade N[c]..	1.3	...	5.0	...	0.5	...	35 000	3.5

[a] Heat treatment No. 1.
[b] Heat treated.
[c] Heat treatment No. 2.

The permeability of a molding sand depends to a great extent upon the size and shape of its individual grains. The coarser grained sands generally have higher permeability values than do fine grained sands, particularly when the grain shape is such as to provide a maximum space between the particles. The sands used for aluminum alloy founding must, however, be fine enough to resist the high sand searching power of the metal. To accomplish this, permeability is sometimes sacrificed to obtain smooth surfaces.

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[1] Metallurgical Engineer, Aluminum Company of America, Cleveland, Ohio.

[2] Tentative Specifications for Aluminum-Base Alloy Sand Castings (B 26 - 37 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 678 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 300.

The effect of sand permeability on the mechanical properties of cast test specimens of alloy G is illustrated in Fig. 1. A wide range of permeability, considerably above that of normal aluminum sands, is included. It will be noted that both tensile strength and elongation increase as the permeability increases.

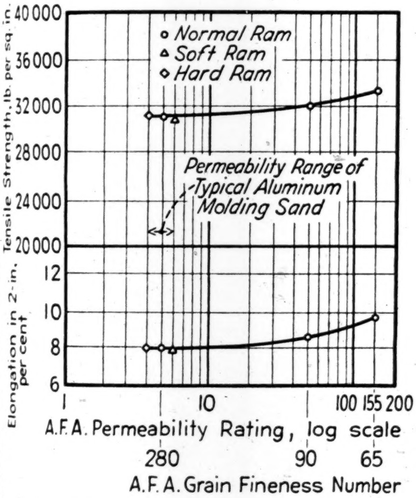


FIG. 1.—Effect of Sand Mold Permeability on the Mechanical Properties of Alloy G, Heat Treatment No. 1.

It is to be expected that mold permeability might decrease somewhat as the sand grains become more and more closely packed by ramming. This is true to a certain extent since the lower permeability of molds in which the sand grains are too closely packed by ramming, often results in what are generally termed "hard ram blows."

Included in Fig. 1 are also data relative to the change in permeability of a sand used extensively for casting aluminum alloys as affected by hard or light ramming. Since this change in permeability was not great, the mechanical properties of test specimens were not noticeably affected.

As an illustration of the influence of the more drastic chilling provided by iron molds, the nominal tensile strengths of several alloys when cast in sand and permanent molds have been compared graphically in Fig. 2. These graphs show the average tensile strengths of test specimens of alloys JJ, C, and N (heat treatment No. 2), when cast in permanent molds to be 26, 17, and 23 per cent higher, respectively, than those of the same alloys cast in normal aluminum foundry sand.

Sand Strength.—Sand strength is also important. If the strength of a molding sand is low, the test bar molds are readily distorted, either while being made or in later handling. Such mold distortion may result in specimens which are imperfect with respect to roundness and straightness. These imperfections may introduce appreciable errors during measuring, testing, and computation of results. Low sand strength may also cause sand dropping or washing, which is of course undesirable, since such sand usually becomes embedded in the test specimen and results in some reduction in mechanical properties.

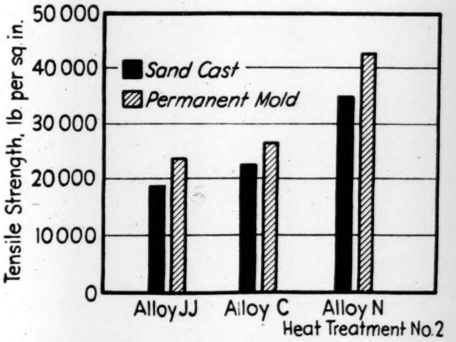


FIG. 2.—Effect of Extreme Chilling on Tensile Strength.

The strength of molding sands generally used for casting aluminum alloys is obtained from a natural clay bond and added moisture. These constituents are generally maintained at percentages sufficient to provide a molding sand strength of about 5 lb. per sq. in. This strength is developed in a sand with a grain fineness of 260 to 300 and a clay content of about 20 to 30 per cent by weight, with 6 to 7 per cent by weight of moisture.

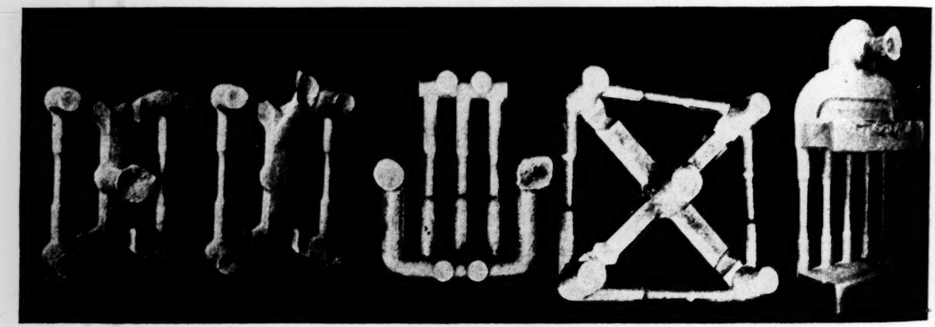
Pattern Equipment.—In addition to the use of suitably controlled molding sands, it is of course also very important to provide good pattern and molding equipment. Loose flasks as well as warped or worn equipment often cause shifting or sagging of the molds and other dimensional irregularities.

GATING DESIGN

The design of a gating for the casting of aluminum alloy test specimens should incorporate such features as to provide a maximum of soundness in the specimens as well as uniformity in conditions surrounding the solidification of the metal in the mold. This is done by the use of well placed sprues and risers together with proper distribution of the metal by means of correctly designed runners and gates.

The number of test specimens to be accommodated on one gate must also be considered carefully since this factor has a marked influence on the economics of the production of test specimens. Since it is preferable from the standpoint of cost to provide more than one test specimen on a gate, the design of the gating should also be such as to provide maximum uniformity among specimens on a single gate.

In order to illustrate the effect of various features of gating designs on the magnitude and uniformity of the mechanical properties obtained, five designs, two of which are widely used, have been selected for discussion. These are illustrated in Fig. 3.



Two Bar — Modified Two Bar — Three Bar — Four Bar — Six Bar

FIG. 3.—Designs of Gatings for the Casting of Aluminum Alloy Test Specimens.

Of the gating designs shown, the 3-bar and 6-bar types are what may be classed as single end gatings, the metal entering the specimen cavity from one end. One disadvantage of this type of gating is the excessive heating of the specimen cavities by the hot metal which runs through them, causing a tendency toward slower solidification and lowered mechanical properties. This is particularly true of the 6-bar mold because of the greater volume of metal involved.

The particular 3-bar type of gating shown has the added disadvantage of providing metal at varying temperatures to the various specimen cavities, reducing the uniformity of the mechanical properties obtained.

The 2-bar and 4-bar types of gatings shown in Fig. 3 may be classed as double end gatings, the metal entering the specimen cavities from both ends. The advantage of this type of gating lies in the more favorable solidification conditions provided by the lower mold temperature. This is obtained by symmetrical gating, which eliminates the flowing of metal completely through the specimen cavity.

The symmetrically gated 2-bar mold has been widely used for a number of years with excellent results. The 4-bar design is an adaptation of a similar design frequently used for other materials. It incorporates the desirable features of the 2-bar design, and the results obtained are comparable with those obtained from that design.

The modified 2-bar design incorporates a slanting sprue, which is offset somewhat from the center of the runner. This was developed to permit the streams of metal from the ends of the specimen cavities to meet in the grip sections, rather than in the gage sections, so as to eliminate oxide films which have been encountered occasionally in the gage section of specimens cast from the magnesium-bearing aluminum alloys. The modified 2-bar gating has been used only on alloys of this type.

The uniformity and magnitude of the tensile strengths obtained from specimens cast in various types of molds are shown in Fig. 4. Cast aluminum alloys G, H and JJ were used in the various comparisons. All specimens were cast under identical conditions except for the gating used. No tests were discarded because of oxide or gas inclusions.

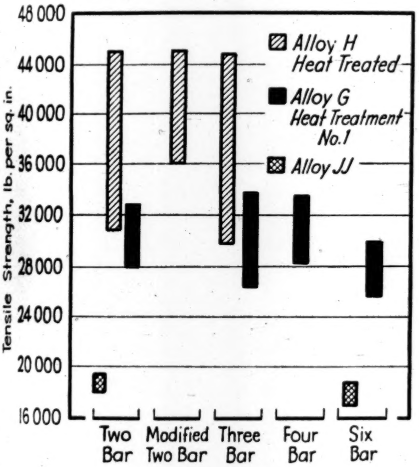


FIG. 4.—Effect of Mold Design on Uniformity of Tensile Strength.

It will be noted that in the tests in which alloy G was used, the spread between maximum and minimum tensile strengths obtained with the 2-bar and 4-bar gatings was less than that of the 3-bar, and slightly more than that of the 6-bar design. The average tensile strengths obtained using the 2-bar and 4-bar gatings were, however, slightly higher than that obtained with the 3-bar design and considerably higher than that obtained with the 6-bar gating.

In the tests involving alloy JJ, the tensile strengths obtained from specimens cast in the 2-bar mold showed slightly less variation than did those cast in the 6-bar molds. The average tensile strength obtained using the 2-bar design was again higher than that of specimens cast in 6-bar molds.

The data representing alloy H (heat treated) show the magnitude and uniformity of the tensile strengths obtained when this alloy was cast in the 2-bar, the modified 2-bar, and the 3-bar molds. These tests illustrate the material improvement in uniformity of the tensile strengths obtained by the change from the vertical to the slanting sprue when using the magnesium-bearing aluminum alloys.

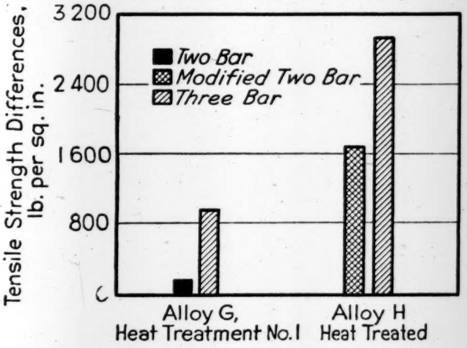


FIG. 5.—Average Variation in Tensile Strength Between Individual Bars From the Same Mold.

Figure 5 summarizes the average differences in tensile strength between the highest and lowest values obtained from individual molds of test specimens of alloys G and H cast in 2-bar and 3-bar molds. These graphs show the specimens cast in the 2-bar type of mold to have a materially lower average difference in tensile strength between specimens in the same mold, than specimens cast in the 3-bar mold.

MELTING CONDITIONS

The melting conditions used for aluminum alloys exert a profound influence on the structure and therefore on the mechanical properties of the cast material. Thus test specimens reflect faulty melting practice in their mechanical properties. In melting aluminum alloys the temperatures are preferably maintained as low as possible not only to minimize oxidation losses and to provide as fine a grain structure as possible in the finished casting, but also to minimize gas absorption. Holding temperatures and times are also kept at a minimum for the same reasons. In the melting and holding process, the absorption of gases, principally hydrogen, at melting and alloying temperatures has been the subject of considerable study. In general, the amount of gas absorbed depends on the alloy, the metal temperature, the time of exposure, and the concentration of gases at the exposed metal surfaces. The most common manifestation of gas absorption is probably that known as pinhole porosity.

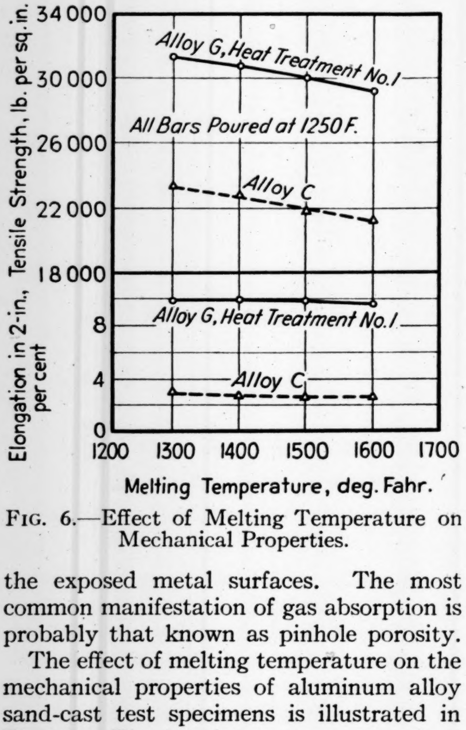


FIG. 6.—Effect of Melting Temperature on Mechanical Properties.

The effect of melting temperature on the mechanical properties of aluminum alloy sand-cast test specimens is illustrated in Fig. 6. The specimens were cast at a temperature of 1250 F., the metal having been heated in melting to temperatures ranging from 1300 to 1600 F. It will be noted that the tensile strengths show a decided drop as the melting temperature is increased, although the elongations were not so noticeably affected.

POURING PRACTICE

The use of careful skimming, the correct pouring temperature, a low pouring height, and the proper pouring speed, are all essential to the production of test specimens of uniform quality.

Since dross or oxide inclusions in the gage section adversely affect the mechanical properties of cast test specimens by reducing the effective cross-section of the specimen, or producing high localized stress concentrations, it is, of course, important that the cleanest possible metal be provided at the mold. To this end it is advantageous to skim the metal at the mold just before pouring.

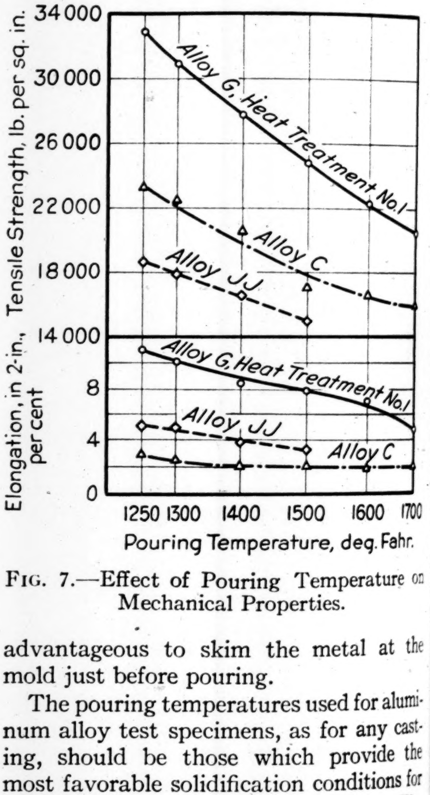
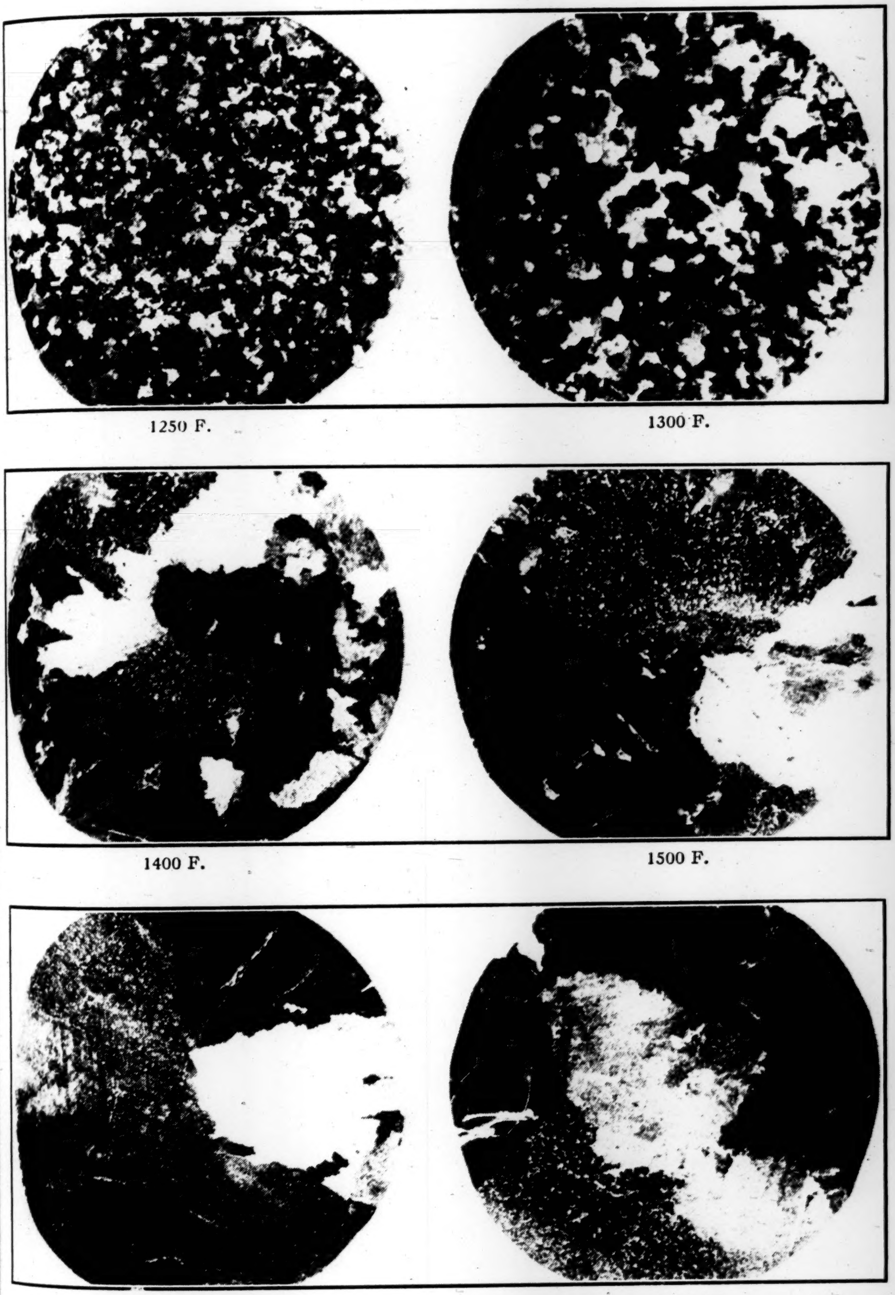


FIG. 7.—Effect of Pouring Temperature on Mechanical Properties.

The pouring temperatures used for aluminum alloy test specimens, as for any casting, should be those which provide the most favorable solidification conditions for the optimum mechanical properties. The pouring temperature which provides these solidification conditions will vary with the section thickness and design of the part being cast. Once the test specimen gating is established, the proper pouring temperature can be readily determined. In the case of the majority of pattern designs for the standard ½-in. diameter aluminum alloy specimens, a pouring temperature of 1250 to 1280 F. has been found to meet



1250 F. 1300 F.

1400 F. 1500 F.

1600 F. 1700 F.

FIG. 8.—Effect of Pouring Temperature on Grain Size of Aluminum Alloy Sand-Cast Test Specimens Poured at Temperature Indicated.

these requirements most adequately, depending on the alloy involved.

Figure 7 illustrates the reduction in mechanical properties obtained by pouring test specimens of alloys C, G and JJ, at temperatures ranging from 1250 to 1700 F. in the 2-bar type of mold. How these temperatures have affected the solidification of these specimens is shown in Fig. 8.

Pouring height and pouring speed, while not generally stressed, are also important factors in the making of aluminum alloy castings. Too great a pouring height may result in the inclusion of trapped air or oxide in the test specimens. The pouring speed should, in general, be that which will fill the mold as quickly as possible without undue metal agitation. The pouring speed is usually limited by the size of the sprue, which sprue should be kept filled in order to prevent excessive metal agitation and to allow oxide and trapped air to float out instead of being forced into the casting.

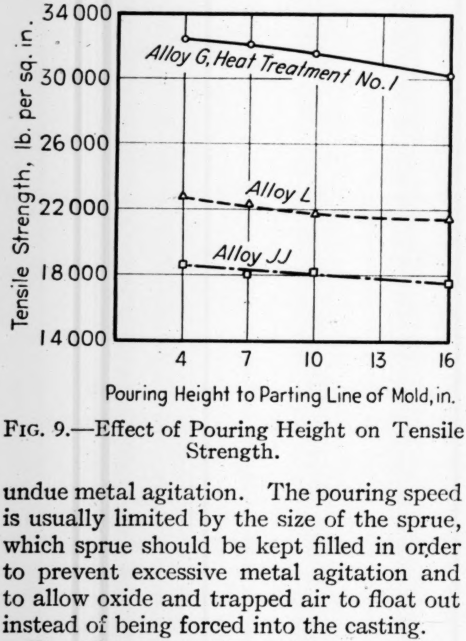


FIG. 9.—Effect of Pouring Height on Tensile Strength.

The effect of pouring height on the tensile strengths of test specimens of alloys G, JJ and L is illustrated in Fig. 9. The curves show the tensile strengths of all of these alloys to be definitely reduced as the pouring height is increased. This reduction probably results from increased amounts of porosity which occur in the specimens as the pouring height is increased.

SHAPE AND SURFACE CONDITION OF SPECIMENS

Variations in surface and shape of tensile specimens, such as shifts caused by weak sand or loose molding equipment, surface roughness caused by rough mold surfaces, and out-of-roundness resulting from drastic rapping of the pattern, may influence materially the observed mechanical properties of tension specimens. This influence may be manifested as errors in measuring specimen diameters, variations in breaking loads resulting from non-axial loading of the specimen, or stress concentrations from surface imperfections. With proper molding technique and equipment, together with the use of appropriate methods for measuring specimen diameters, the effects of these variables can be minimized.

During the shaking out, identifying, trimming, and heat treating, care must be exercised to prevent marring the surface bending or otherwise damaging the specimens. Such damage may result from shaking out the molds while too hot, striking the specimens too hard when stenciling identification numbers on them, nicking the gage sections in trimming, and improper packing during heat treatment.

In view of the foregoing considerations, some foundries prefer the option of casting aluminum alloy tension test specimens to somewhat larger diameters than the standard 0.505 in. in order to permit the machining of the gage sections to final dimensions. The effect of such machining on the mechanical properties of test specimens of alloy G has been investigated. In this investigation, test specimens cast to 0.565-in. diameter using the 2-bar gating were machined to a diameter of 0.505 in. and the mechanical properties compared with those of standard cast-to-size specimens from the same melts of metal and using the same gating.

These tests, which included approximately 150 specimens of each type, showed the mechanical properties of the cast-to-size and machined specimens to be practically identical in magnitude and uniformity.

CUMULATIVE EFFECT OF FOUNDRY VARIABLES

Many of the variables discussed may not, in themselves, result in a sufficient reduction in the strength of aluminum alloy test specimens, to be considered serious. However, the cumulative effect of several of these insignificant conditions may become appreciable. In fact, the difficulty experienced in diagnosing the cause of low properties in many cast test specimens is often due to the fact that they are the result of several factors rather than a single one.

It is, of course, not correct to assume that the effects of all the individual factors mentioned are numerically additive. It is quite possible, however, to reduce the tensile strength of aluminum alloy test specimens as much as 40 per cent by the cumulative effect of the conditions considered. The necessity of strict control in all phases of the production of such specimens is therefore essential if the subsequent tension tests are to be of maximum value.

SUMMARY

The experience and data available to date indicate that the various factors discussed have certain general effects on the mechanical properties of sand-cast aluminum alloy test specimens. It is realized that these effects may vary in magnitude, depending on the combination of factors involved in each production or experimental case. The general effects which have been noted are summarized below:

1. The strength of sand-cast test specimens may be improved by increasing the permeability of the sand, the increase apparently being due to the more ready escape of insulating mold gases and added chilling effect.
2. The changes in permeability, resulting from hard or soft ramming of a typical aluminum foundry sand, were not significant, and the mechanical properties of test specimens were not noticeably affected by these differences when cast in this sand.
3. The use of good flask and pattern equipment, sand of adequate strength and careful molding technique are required to prevent dimensional distortions in test specimen molds and subsequent errors in the computed strengths.
4. A comparison of the uniformity and magnitude of the mechanical properties obtained from test bars cast in molds of several designs would seem to indicate that the 2-bar design with a slanting sprue for aluminum alloys such as alloys H, L and N of Table I, and a straight sprue for other aluminum alloys, generally produce more consistent and higher mechanical properties than the other designs investigated.
5. The mechanical properties of test specimens are reduced by increased melting and pouring temperatures. High temperatures result in an increase in grain size by reducing the solidification rate and an increase in unsoundness resulting from gas absorption.
6. Unsoundness resulting from inefficient cleaning of metal and pouring conditions causes an appreciable reduction in strength of sand-cast test specimens.
7. The machining of 0.505-in. diameter test specimens from 0.565-in. diameter test specimens of alloy G, cast in a 2-bar mold, resulted in no significant difference in mechanical properties.

Acknowledgement.—The author wishes to acknowledge the assistance of Mr. M. H. Gould in carrying out the various tests and preparing the data.

REPORT OF JOINT COMMITTEE
ON
EXPOSURE TESTS OF PLATING ON THE NON-FERROUS METALS

Introduction:

Since this committee was organized in 1935, its membership has been increased by two additional persons each from the American Society for Testing Materials and the American Electroplaters' Society. It is now constituted as follows:

	REPRESENTING
William Blum, chairman, National Bureau of Standards, Washington, D. C.	N.B.S.
T. H. Chamberlain, New Haven Clock Co., New Haven, Conn.	A.E.S.
B. H. McGar, Chase Brass and Copper Co., Waterbury, Conn.	A.E.S.
C. F. Nixon, Ternstedt Division, General Motors Corp., Detroit, Mich.	A.E.S.
W. M. Phillips, General Motors Corp., Detroit, Mich.	A.E.S.
W. A. Wesley, International Nickel Co., Bayonne, N. J.	A.E.S.
C. H. Sample, Bell Telephone Laboratories, New York City.	A.S.T.M., Committee A-5
J. R. Freeman (Alternate A. W. Tracy), American Brass Co., Waterbury, Conn.	A.S.T.M., Committee B-3
Sam Tour, Lucius Pitkin, Inc., 47 Fulton St., New York City.	A.S.T.M., Committee B-3
J. C. Fox, Doehler Die Casting Co., Toledo, Ohio.	A.S.T.M., Committee B-6
Carl Heussner, Chrysler Corp., Detroit, Mich.	A.S.T.M., Committee B-6

Program:

The specimens listed in the 1936 report[1] of the Joint Committee were exposed in 1936 in six locations. Since then they were inspected at regular intervals and in general yielded consistent results. After discussion of these data at a conference in Chicago, Ill., on March 3, 1937, it was decided to prepare and expose certain supplemental specimens, in order to confirm or extend the results obtained with the original sets. The new specimens were prepared at the National Bureau of Standards by P. W. C. Strausser and J. P. Huff, employed on the Research Fund of the American Electroplaters' Society.

At a meeting in New York City in June, 1937, it was decided to include some zinc-base die castings plated in commercial plants with coatings of known thickness. These were accordingly made under the supervision of P. W. C. Strausser, A.E.S. Research Associate, in the plants of the Ternstedt Division of General Motors Corp., Detroit; the W. B. Jarvis Co., Grand Rapids; and the Philip Sievering Co., New York City. In all of these plants bright nickel coatings were regularly employed, and were therefore applied to these specimens. The compositions of these bright nickel baths were not disclosed.

At a meeting in Washington, D. C., on October 6, 1937, it was decided to include certain specimens plated with bright nickel at the National Bureau of Standards from proprietary solutions, the compositions of which will not be disclosed. The specimens plated by the different bright processes have been marked alike and are indistinguishable from each other, so that the results of exposure tests will merely show whether, on the average, bright nickel deposits differ materially in their protective action from plain nickel deposits of the same thickness. These specimens were plated at the National Bureau of Standards with the cooperation of the McGean Chemical Co., Harshaw Chemical Co., Hanson-Van Winkle-Munning Co., and the Pyrene Mfg. Co.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 212 (1936).

Special equipment and materials required were donated by the following firms:

Vapor degreasing equipment—Detroit Rex Products Co.
Trichlorethylene—Detroit Rex Products Co.
Nickel anodes—International Nickel Co.
Buffing compounds—Hanson-Van Winkle-Munning Co.
Buffs—Hanson-Van Winkle-Munning Co.
Copper anodes—Revere Copper and Brass Co.

TABLE I.—COATINGS ON STEEL.

Set	Steel	Coating	Coating Thickness, in.			Variation
			Copper	Nickel	Chromium	
No. S 101 A	No. I	Ni, Cr	......	0.001	0.00002	Standard Ni, Cr
No. S 109 A	No. I	Cu (Cy), Ni, Cr	0.0005	0.0005	0.00002	Copper layer
No. S 109 B	No. I	Cu (Cy), Ni, Cr	0.0005	0.0005	0.00002	Bright nickel
No. S 181 A	No. II	Ni, Cr	......	0.001	0.00002	Like S 101 A, different steel
No. S 189 A	No. II	Cu (Cy), Ni, Cr	0.0005	0.0005	0.00002	Like S 109 A, different steel
No. S 189 B	No. II	Cu (Cy), Ni, Cr	0.0005	0.0005	0.00002	Like S 109 B, different steel

TABLE II.—COATINGS ON ROLLED HIGH BRASS.

Set	Coating	Coating Thickness, in.		Variation
		Nickel	Chromium	
No. B 31 A	Ni, Cr	0.0002	0.00002	Standard Ni, Cr
No. B 31 B	Ni, Cr	0.0002	0.00002	Bright nickel
No. B 31 C	Ni, Cr	0.0002	0.00002	No organic degreaser
No. B 32 A	Ni, Cr	0.0001	0.00002	Thickness nickel
No. B 33 A	Ni, Cr	0.0002	0.00003	Thickness chromium
No. B 34 A	Ni, Cr	0.0005	0.00002	Thickness nickel
No. B 34 B	Ni, Cr	0.0005	0.00002	Bright nickel
No. B 35 A	Ni, Cr	0.0002	0.00001	Thickness chromium
No. B 36 A	Ni, Cr	0.0003	0.00002	Thickness nickel
No. B 37 A	Ni, Cr	0.0002	0.00005	Thickness chromium
No. B 38 A	Ni	0.0002	....	No chromium
No. B 47 A	Ni, Cr	0.00005	0.00002	Thickness nickel
No. B 56 A	Ni, Cr	0.00015	0.00002	Thickness nickel
No. B 57 A	Ni, Cr	0.001	0.00002	Thickness nickel
No. B 58 A	Ni, Cr	0.0002	0.000005	Thickness chromium
No. B 59 A	Ni, Cr	0.0002	0.00002	Brass bright dipped

Equipment and Materials:

The base metals used in these supplemental tests had the compositions listed under the same numbers in the 1936 report.[1] They were donated by the following firms:

No. I—Cold-rolled steel. American Steel and Wire Co.
No. II—Full cold-rolled steel. The Stanley Works
No. X—Rolled high brass. Chase Brass and Copper Co.
No. XXI—Zinc alloy die castings. New Jersey Zinc Co.
No. XXIII—Zinc alloy die castings. New Jersey Zinc Co.

Nickel carbonate—Harshaw Chemical Co.
Nickel chloride—Harshaw Chemical Co.
Nickel sulfate—Harshaw Chemical Co.
Anode bags—Harshaw Chemical Co.
Rochelle salt—Grasselli Chemical Dept., E. I. du Pont de Nemours and Co., Inc.
Boric acid—Grasselli Chemical Dept., E. I. du Pont de Nemours and Co., Inc.
Chromic acid—Mutual Chemical Co. of America.
Sodium metasilicate—Philadelphia Quartz Co.

Schedule of Deposits:

In the following tables, "Cy" refers to a Rochelle salt - cyanide copper bath; "S" to a standard nickel bath, and "HS" to a high-sulfate - nickel bath.

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[1] *Loc. cit.*

The bath compositions and the details of the cleaning and plating processes were given in a report of P. W. C. Strausser to the American Electroplaters' Society in Milwaukee, Wis., on June 13, 1938, and will be published in the A.E.S. *Monthly Review.*

TABLE III.—COATINGS ON ZINC DIE CASTINGS.

Set	Die Casting	Coating	Coating Thickness, in.			Variation
			Copper	Nickel	Chromium	
No. Z 22 A	No. XXIII	Ni (HS), Cr	......	0.0005	0.00002	Thickness nickel
No. Z 24 A	No. XXIII	Ni (HS), Cr	......	0.0003	0.00002	Thickness nickel
No. Z 35 A	No. XXIII	Ni (HS), Ni (S), Cr	......	0.0003 0.0002	0.00002	"Duplex" nickel
No. Z 37 A	No. XXIII	Ni (HS), Ni (S), Cr	......	0.0003 0.0007	0.00002	Thickness duplex nickel
No. Z 38 A	No. XXIII	Ni (HS), Ni (S), Cr	......	0.0003 0.0017	0.00002	Thickness duplex nickel
No. Z 40 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.0002	0.0003	0.00002	Copper layer
No. Z 41 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.0004	0.0006	0.00002	Thickness copper layer
No. Z 42 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.0005	0.0015	0.00002	Thickness copper layer
No. Z 48 A	No. XXIII	Ni (HS), Cr	......	0.0002	0.00002	Thickness nickel
No. Z 51 A	No. XXIII	Ni (HS), Cr	......	0.00075	0.00002	Thickness nickel
No. Z 52 A	No. XXIII	Ni (HS), Ni (S), Cr	......	0.0003 0.00045	0.00002	Standard, duplex nickel
No. Z 53 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Standard, copper, nickel
No. Z 53 B	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel
No. Z 53 E	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel In commercial plant
No. Z 53 G	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel In commercial plant
No. Z 53 H	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel In commercial plant
No. Z 54 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00001	Thickness chromium
No. Z 55 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00003	Thickness chromium
No. Z 56 A	No. XXIII	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00005	Thickness chromium
No. Z 61 A	No. XXI	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Like Z 53 A, different alloy
No. Z 61 B	No. XXI	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel
No. Z 61 E	No. XXI	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel In commercial plant
No. Z 61 G	No. XXI	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel In commercial plant
No. Z 61 H	No. XXI	Cu (Cy), Ni (S), Cr	0.00025	0.0005	0.00002	Bright nickel In commercial plant

Exposure Tests:

Specimens of the sets shown in Tables I, II and II have just been exposed at Key West, Fla., New York City, Pittsburgh, Pa., Sandy Hook, N. J., State College, Pa., and Washington, D. C. In Pittsburgh the racks have been moved from Brunot Island to the U. S. Bureau of Mines to obtain a less severe, but still industrial, location. Certain of the original specimens that were still in fair condition have been retained in each location.

Inspections will be made by members of the Joint Committee and other interested persons, who may secure a schedule from the chairman. As soon as the results warrant definite conclusions or recommendations, these will be published.

The committee desires to thank those firms that have donated materials or equipment for this investigation and those persons who have assisted in the inspections.

Respectfully submitted on behalf of the Joint Committee,

W. BLUM,
Chairman.

REPORT OF COMMITTEE C-1
ON
CEMENT

Committee C-1 on Cement held two meetings during the year. Both of these were well attended, including as usual a considerable number of nonmembers who were much interested in the committee's activities. As a result of its work the committee is presenting revisions of the specifications for portland cement, high-early-strength portland cement, masonry cement, tentative methods of chemical analysis, and the turbidimeter test for fineness of portland cement.

Masonry Cement:

The present Tentative Specifications and Tests for Masonry Cement (C 91 – 32 T) were published as tentative in 1932. Since then there has been an extended development of this commodity and its use has increased considerably. Its wide use has been accompanied by studies which have added much to the available information. With this at hand the committee has made two outstanding revisions of the present tentative specifications: first, a marked increase in the strength requirements, and, second, a requirement covering the change in workability of mortars produced by the removal of some of the mixing water. These specifications in their revised form are appended hereto.[1]

Portland Cement:

When the committee prepared Standard Specifications for High-Early-Strength Portland Cement (C 74 – 36) it obligated itself to revise the Standard Specifications for Portland Cement (C 9 – 37) in so far as the question of a definition for portland cement was concerned. This is a matter of considerable importance, since Specifications C 74 not only lack a definition but also include a statement which permits the use of less than 1 per cent additions, subsequent to calcination of the clinker, of other than water and/or untreated calcium sulfate, if found not to be harmful by tests prescribed and carried out by Committee C-1. The committee is now submitting for immediate adoption a revision, as given in the Appendix to this report, of the Standard Specifications for Portland Cement (C 9 – 37) which proposes the deletion of the first paragraph containing the definition and the inclusion, after the table in Section 2, of the paragraph and note that follow the table in Section 1 of Specifications C 74. The two standards for portland cement will then be in agreement on the question of admixtures, and in having a similar paragraph descriptive of the nature of the commodity.

High-Early-Strength Portland Cement:

The committee is also presenting for immediate adoption a revision of the Standard Specifications for High-Early-Strength Portland Cement (C 74 – 36) comprising the deletion of the requirement covering the fineness of the cement, as indicated in the Appendix to this report. The committee in so doing is in accord with the widely accepted thought that the fineness of a cement is a detail of a manufacturing nature of much importance to the producer and, although it is reflected in the physical properties of a cement, it is adequately covered so far as the user is concerned by several other physical requirements. This action brings the Society's standards for cements of the portland type into conformity with one another in so far as fineness is concerned, the fineness requirement in Specifications C 9 having been dropped in 1937.

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[1] See p. 731.

Blended Cement:

The Proposed Tentative Specifications and Methods of Test for Blended Cements, submitted by the committee last year, when presented to the Society at the 1937 annual meeting failed to secure the votes necessary for its acceptance for publication as tentative. The Working Committee on Blended Cements (R. E. Roscoe, chairman) responsible for the preparation of these specifications contacted all who it knew were opposed to the acceptance of the specifications, in order to secure their criticisms. These were analyzed and the subcommittee, after due consideration, made the following amendments to the Proposed Tentative Specifications and Methods of Test for Blended Cements, as published with the 1937 report of the committee:[1]

Section 2.—Change the definition of blended cement to read as follows by the addition of the italicized words:

2. A blended cement is the finely divided product obtained by intimately mixing together, preferably by intergrinding, portland cement and *more than 1 per cent of* one or more admixtures (other than the material used to regulate the set of portland cement) which are added to alter one or more properties of the cement.

Section 10.—Change the requirements for compressive strength to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

10. (*a*) The average compressive strength of not less than three [3 by 6] *2*-in. concrete [cylinders] *cubes* shall be not less than *1500 lb. per sq. in. in at 3 days,* [1000] *2500* lb. per sq. in. at 7 days, and [2000] *4000* lb. per sq. in. at 28 days.

(*b*) In case the purchaser desires a cement developing high-early strength, he may specify that the concrete develop an average compressive strength of [1000] *2000* lb. per sq. in. at 1 day, [and 2000] *3500* lb. per sq. in. at 3 days, *and 4000 lb. per sq. in. at 7 days.* [The purchaser may also require that the compressive strength of the concrete shall be not less than 3000 lb. per sq. in. at 28 days.]

(*c*) In case the purchaser specifies a cement having *a* low heat of hydration (Section 11) the average compressive strength of concrete shall be not less than *1000 lb. per sq. in. at 3 days,* [750] *1800* lb. per sq. in. at 7 days, and [1500] *3000* lb. per sq. in. at 28 days.

(*d*) The compressive strengths [obtained] at 28 days shall be greater than those obtained at 7 days and *those at 7 days shall be greater than those obtained at 3 days. In addition,* in the case of the high-early-strength cements the strengths at 3 days shall be greater than the strengths at 1 day.

(*e*) *The compressive strength tests shall be made in accordance with Section 22.*

Section 11.—Change the requirements for heat of hydration from their present form: namely,

11. (*a*) The heat of hydration shall not exceed 75 cal. per g. at 7 days and 85 cal. per g. at 28 days when tested in accordance with the method described in Sections 23 and 24.

NOTE.—Emphasis is placed on the fact that the method for determining the heat of hydration as described in Section 23 is intended for portland cement. Some of the blended cements might contain material which is dissolved with difficulty, in which case complete solution may not be obtained in this test.

(*b*) The purchaser, if he desires, may specify that the heat of hydration shall not exceed 65 cal. per g. at 7 days and 75 cal. per g. at 28 days. In this event, however, the average compressive strength of the concrete may be lower but shall be not less than 750 lb. per sq. in. at 7 days and 1500 lb. per sq. in. at 28 days as provided in Section 10 (*c*).

to read as follows:

11. (*a*) If the purchaser desires a cement having low heat of hydration, the heat of hydration shall not exceed 65 cal. per g. at 7 days and 75 cal. per g. at 28 days. In this event, however, the average compressive strength of the concrete may be lower but shall not be less than that specified in Section 10 (*c*).

(*b*) In case of ordinary blended cements, if the purchaser so desires he may require that the cement be tested for heat of hydration, in which case the heat of hydration shall not exceed 75 cal. per g. at 7 days and 85 cal. per g. at 28 days.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 291 (1937).

(*c*) In case the purchaser desires that high-early-strength cement be tested for heat of hydration it shall not exceed 110 cal. per g. at 7 days and 125 cal. per g. at 28 days.

(*d*) The heat-of-hydration tests shall be made in accordance with Sections 23 and 24.

NOTE.—Emphasis is placed on the fact that the method for determining the heat of hydration as described in Section 23 is intended for portland cement. Some of the blended cements might contain material which is dissolved with difficulty, in which case complete solution may not be obtained in this test.

Section 22.—Change the compressive strength test from its present form: namely,

22. The concrete for the compression test specimens shall be mixed with a water-cement ratio of 1.0 and it shall have a slump of from 2 to 4 in. The coarse aggregate shall be sound and well graded. The sand shall be graded. The cement-sand relation by volume should be held close to 1:2. The procedure for mixing, molding, and testing of the specimens shall conform to that described in the Standard Methods of Making Compression Tests of Concrete (A.S.T.M. Designation: C 39) of the American Society for Testing Materials.

to read as follows:

22. (*a*) Compressive strength tests shall be made in accordance with the Tentative Method of Test for Compressive Strength of Portland-Cement Mortars (A.S.T.M. Designation: C 109 – 37 T) of the American Society for Testing Materials, with the following exceptions:

(*b*) The following quantities of materials will be sufficient for a six-cube batch:

Low absorption gravel[a] ($\frac{3}{8}$ in. to No. 4)	1350 g.
Standard Ottawa sand[b] (Nos. 20 to 30)	790 g.
Potter's flint[b]	110 g.
Cement	450 g.
Cement-water ratio, *C/W*, by weight	1.88
Water-cement ratio, *W/C*, by volume	0.8
Water	239 ml.

[a] The low-absorptive (0.4 per cent) pebbles may be purchased in 100-lb. lots from the Lawrence Stone and Gravel Co., Columbia, S. C.

[b] The sand and Potter's flint may be purchased in 100-lb. lots from the Ottawa Silica Co., Ottawa, Ill.

(*c*) The mixes shall be made to slump within a range of $1\frac{5}{8}$ to $2\frac{3}{8}$ in. by adding to or deducting from the basic mixes, when necessary, cement and water in the ratio of 1.88 by weight (water-cement ratio 0.8 by volume). The slump test shall be made in accordance with the Tentative Method of Test for Consistency of Portland-Cement Concrete (D 138 – 32 T) of the American Society for Testing Materials except that the cone shall be one-half size (2 by 4 by 6 in.) and filled in two layers and rodded with a $\frac{3}{8}$-in. bullet-pointed rod.

The revised proposed specifications were presented by the Working Committee on Blended Cements to Committee C-1 at its spring meeting. The live discussion which resulted showed the deep interest in the question, but the vote of the committee was not favorable to submitting the specifications to the required letter ballot of the committee.

Methods of Chemical Analysis:

Under the chairmanship of Mr. W. C. Hanna the Working Committee on Methods of Chemical Analysis has continued its marked activity. Work has gone forward by a group of cooperating laboratories, as a result of which an alternate quick method for the determination of manganic oxide has been prepared, as appended hereto.[1] The cooperative work on the determination of sodium oxide and potassium oxide has also resulted in the preparation of new methods, as appended hereto.[1] The three new methods are being presented for publication as tentative and will be incorporated in the Tentative Method of Chemical Analysis of Portland Cement (C 114 – 37 T). The committee is also recommending that the acid-alkali method for rapid determination of magnesia and the method for the rapid determination of magnesia by titration of magnesium oxyquinolate, covered in Sections 1, 2, 3, and 4 of Tentative Method C 114, be referred to letter ballot of the Society for adoption as standard, after minor editorial revisions as indicated in the report of the subcommittee appended hereto.

Work has been continued with another method for the determination of phosphorus pentoxide, but the committee is not ready to make any revision in its present method of determining this constituent in cement. A very extended cooperative series of tests for the determination of free lime in cement is under way. Bearing in mind that the Society's methods for chemical analysis for certain of the oxides in cement are intended to be of a precise and accurate nature, and hence not rapid, the committee is giving thought to the preparation of quicker methods for silica, lime, and magnesia, and also direct methods for determining alumina and titanium oxide. A rather detailed report of the work of this very active subcommittee is appended.

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[1] See p. 738.

Plastic Mortars:

The Working Committee on Plastic Mortar Tests for Portland Cement (O. L. Moore, chairman) feels that the results of its studies to date do not justify any change in the present Tentative Method of Test for Compressive Strength of Portland-Cement Mortars (C 109 – 37 T).

The data which it has accumulated using approximately a $\frac{3}{8}$-in. pebble aggregate as part of a concrete mix in a 2-in. cube have proved most interesting, but the committee does not think it desirable to suggest its tentative use now. Some of the data obtained during the progress of this work are given in the report of the working committee appended hereto. Work is now under way on the use of sand having the size and proportion characteristics of the graded sand now being used in Germany for the testing of cement. This produces a far more workable mortar than that obtained by using Tentative Method C 109, but there is more separation of water after molding than is the case with the large aggregate mortars.

Fineness:

With the deletion of the fineness requirement from the Standard Specifications for Portland Cement (C 9 – 37), and for High-Early-Strength Portland Cement (C 74 – 36), it might appear that the Working Committee on Fineness (J. C. Pearson, chairman), has completed its assigned task. However, believing that there is a relation between the fineness of cement and the amount of water which might separate after molding and before initial set, the committee has done some preliminary work on this important question of water separation or "bleeding." It has been using a method suggested by Mr. E. W. Reed-Lewis. It is still too early to say much about what has been accomplished or the significance of the tests, but the results seem to show among other things that "bleeding" is a function of more than the fineness of the cement and justify the continuation of the work on a larger scale.

The Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 – 34 T) was accepted for publication as tentative in 1934. Since then this method has been used widely, and in the interim a number of constructive criticisms have been received. These have been embodied in revisions of Tentative Method C 115 which are being submitted by the committee, as given in detail in the Appendix to this report. The sections of the method which have been amended are Sections 6, 7, 10(*b*), 11, 13(*a*), and 14(*e*). It will be noted that none of these modifications materially change the test procedure; indeed, the changes might be considered largely editorial.

Attention should again be called to the fact that if the committee's recommendations are adopted at this meeting of the Society, there will be no fineness requirements in the specifications for cement of the portland type. However, since the turbidimetric method of determining the fineness of cement is widely used by producers and by certain users, even though they may not use it in purchase requirements, the committee believes that the method should be one of the Society's standards.

Volume Changes:

The Working Committee on Volume Change and Soundness of Portland Cement (H. F. Gonnerman, chairman) with the assistance of a group of laboratories completed a series of tests of 35 cements (21 portland cements, 6 high-early-strength cements, 3 moderate-heat cements, 3 portland pozzolan cements, and 2 sulfate-resisting cements of the portland type). In these the principal feature was the determination of the expansion of neat bars of the cements when subjected to an autoclaving at a pressure of 295 lb. per sq. in. A number of variables in test procedure were also introduced, particularly such as the amount of water used in mixing the paste, length of bar, and time of autoclaving. The objective was to determine limits for the specifications covering expansion caused by autoclaving, tolerances in the requirements if needed, and the development of a satisfactory test procedure. The report of the committee and a recommended test procedure are appended hereto. The approval of the method will come up for consideration in Committee C-1 at its June meeting. At the same time the Sponsoring Committees on Portland Cement (W. H. Klein, chairman) and on High-Early-Strength Cement (M. A. Swayze, chairman) will present recommended requirements for the autoclave tests for these two types of portland cement. It will be noted in the appended report that a few other data were obtained by some of the cooperating laboratories. Some of these, such as the very complete chemical analyses, Paul's floc test, and Merriman's clear sugar solution determination, should be of much interest.

Cement Reference Laboratory:

The fifth tour of inspection of cement testing laboratories has been completed. That this service has been of value is without question, and that it is appreciated is equally evident from the many complimentary comments received.

The Reference Laboratory is now engaged in distributing to about 170 laboratories a sample of cement for chemical analysis and physical tests. These have indicated their desire to cooperate in assisting the committee to obtain a broad cross-section of the ability of the country's cement testing laboratories to carry out standard test methods with some degree of reproducibility of one another's results.

A report of the subcommittee is appended.

Additions to Portland Cement:

As mentioned in the report last year, the committee has had under way a study of one addition to portland cement. This series of tests to determine if this grinding medium has been harmful to three high-early-strength portland cements has been completed. The Subcommittee on Tests of Additions to Cement (Inge Lyse, chairman), which has supervision of this work at the Cement Reference Laboratory, reported to the chairman of Committee C-1 as follows, under date of June 10, 1938:

> The Subcommittee on Tests of Additions to Cement, of A.S.T.M. Committee C-1, met in Knoxville, Tenn., on April 15. All members of the subcommittee were present, as was Mr. Dwyer of the Cement Reference Laboratory. After a careful study of the data of the tests which had been performed in accordance with the program previously reported to Committee C-1, the subcommittee adopted the following report:
>
> > The subcommittee unanimously considers the results of these tests a fair basis on which to make a definite statement to Committee C-1 and has decided after an examination of the test data that the material known commercially as "TDA," when interground with high-early-strength port-

land cement in amounts not exceeding those used in the cements tested in this study, has been shown to be not harmful within the meaning of the requirement given in Section 1 of A.S.T.M. Specifications C 74 – 36.

The maximum amount of TDA used in the cements tested in this investigation was approximately 0.14 per cent by weight of the cement.

On behalf of the Subcommittee I hereby submit this report to you, the chairman of Committee C-1.

(Signed) Inge Lyse
Chairman, Subcommittee
on Tests of Additions to Cement

Recommendations Affecting Standards:

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 73 voting members, the results being shown in Table I.

This report has been submitted to letter ballot of the committee which consists of 73 voting members; 63 members returned their ballots, of whom 62 voted affirmatively and 0 negatively.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. REVISIONS OF TENTATIVE STANDARDS			
Specifications and Tests for Masonry Cement (C 91 – 32 T)	60	0	2
Method of Chemical Analysis of Portland Cement (C 114 – 37 T):			
New quick method for determining manganic oxide in cement	56	0	6
New method for determining potassium oxide and sodium oxide in cement, and new method for determining water-soluble alkali in cement	47	0	7
Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 – 34 T)	56	2	5
II. REVISIONS OF STANDARDS			
Specifications for Portland Cement (C 9 – 37), immediate adoption[a]	50	10	3
Specifications for High-Early-Strength Portland Cement (C 74 – 36), immediate adoption	47	3	7
III. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method of Chemical Analysis of Portland Cement (C 114 – 37 T), Sections 1 to 4	47	0	7

[a] The classified vote on the adoption of the proposed revision of the Standard Specifications for Portland Cement (C 9 – 30) was as follows: Affirmative: 26 producers, 14 consumers, 10 general interests; negative: 6 producers, 2 consumers, 2 general interests.

Upon receipt of the above report the chairman of Committee C-1 conveyed the information to the Secretary-Treasurer of the Society, who in turn advised the Dewey and Almy Chemical Co. accordingly, that company having arranged for these tests of TDA.

Respectfully submitted on behalf of the committee,

P. H. BATES,
Chairman.

L. W. WALTER,
Secretary.

REPORT OF WORKING COMMITTEE ON METHODS OF CHEMICAL ANALYSIS

Methods for Sodium and Potassium Oxides:

The Working Committee on Methods of Chemical Analysis is pleased to report that the investigation of methods for the determination of potassium and sodium oxides in portland cement has been completed. It is now possible to recommend two methods for consideration for publication as tentative, one for total potassium and sodium oxides and the other for water-soluble alkali.

Attention is called to Table I which shows not only results from ten laboratories but also comments in an abstracted form, a brief description of the methods, probable errors for the means, average probable errors for the methods, and the names of the cooperating laboratories.

It is the opinion of the Working Committee that either Method I or Method II is suitable for acceptance as a tentative method, but it will require much thought to choose between them. The probable errors show Method II to be slightly better than Method I in regard to K_2O. The situation is reversed in the case of Na_2O. It is a matter of opinion as to whether the superiority of one method over the other in either case has been demonstrated.

It has been the belief of the Working Committee that it need not necessarily develop the quickest methods for the chemical analysis of portland cement, but the element of time is taken into consideration to some extent in the evaluation of methods.

Method II departs from the standard practice in two ways: (*1*) sulfuric anhydride is not removed with a solution of barium chloride and thus the problem of removing excess barium chloride is absent; (*2*) the precipitate of potassium chloroplatinate is washed with a special solution to remove sodium sulfate that may contaminate the precipitate. This method has been used with success in the laboratories of the Universal Atlas Cement Co. for many years. It is similar to the method known as the Lindo-Gladding Method.[1] Before the beginning of the investigation, G. E. F. Lundell of the National Bureau of Standards was kind enough to review the methods critically. Method II appeared to him to be sound in principle, although he suggested a few minor alterations which have since been accepted.

It is to be noted that Method II gave slightly higher results than Method I in most cases, but there is no evidence as to which set of results is nearer the truth. It requires greater care to evaporate sulfates to dryness than to evaporate chlorides but the danger of loss through volatilization at red heat is greater with chlorides than with sulfates.

From the viewpoint of precision, the investigation has shown Method II to be equal to Method I which represents standard practice. The former is simpler and easier to follow than the latter. For these reasons the Working Committee favors Method II as a tentative method for the determination of sodium oxide and potassium oxide in portland cement. The method as rewritten in A.S.T.M. form is appended hereto.[2] Sections 7 and 8 of the proposed procedures deal

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[1] W. F. Hillebrand and G. E. F. Lundell, "Applied Inorganic Analysis," p. 534, John Wiley and Sons, New York City (1929); also *Chemical News*, Vol. 53, pp. 202 and 296 (1886).

[2] See p. 738.

TABLE I.—ANALYTICAL DATA FROM COOPERATIVE INVESTIGATION OF METHODS FOR THE DETERMINATION OF ALKALI IN PORTLAND CEMENT.

Samples K and L are normal portland cements.
Method I: J. Lawrence Smith Method.
Method II: Modification of J. Lawrence Smith Method as used by Universal Atlas Cement Co. The mixed chlorides are converted to sulfates and weighed as such before the separation of K_2PtCl_6.
Method III: Berk and Roller Method, published in *Concrete*, Cement Mill Edition, Vol. 43, No. 3, pp. 38 and 39, March, 1935.
Method IV: Modification of method for water-soluble alkali as used by the U. S. Treasury Dept. The alkali is leached out of cement with water and weighed as sulfate. For convenience, all alkali as obtained is reported as soda, though potash may be present.

Laboratory	K_2O						Na_2O						Water-Soluble Alkali as Na_2O by Method IV		Abstract of Comments on Methods
	Sample K			Sample L			Sample K			Sample L					
	Method I	Method II	Method III	Method I	Method II	Method III	Method I	Method II	Method III	Method I	Method II	Method III	Sample K	Sample L	
No. 1	0.26	0.26	0.34	0.61	0.61	0.69	0.48	0.53	0.53	0.39	0.55	0.48	0.11	0.37	Method I is best. Method II is less satisfactory because it is harder to evaporate sulfates than chlorides. Method III is very troublesome.
No. 2	0.25	0.30	0.39	0.60	0.62	0.79	0.42	0.43	0.56	0.37	0.37	0.46	0.13	0.40	Methods I and II seem very cumbersome. Several requirements are needless.
No. 3	0.26	0.25	0.30	0.60	0.59	0.62	0.47	0.52	0.56	0.37	0.42	0.45	0.11	0.42	Methods I and II are good. Method III is unsuitable as a specification.
No. 4	0.30	0.34	0.58	0.64	0.64	1.16	0.47	0.47	0.58	0.45	0.44	0.44	0.12	0.41	Further simplification is possible for Methods I and II.
No. 5	0.24	0.24	0.24	0.59	0.59	0.67	0.45	0.47	0.57	0.37	0.41	0.45	0.10	0.42	Method III appears to be best in spite of slow filtration.
No. 6	0.23	0.24	0.26	0.59	0.58	0.61	0.46	0.49	0.52	0.39	0.46	0.44	0.11	0.37	No comment.
No. 7	0.25	0.26	0.25	0.42	0.46	0.48	0.46	0.49	0.53	0.55	0.56	0.59	0.13	0.41	Method III is highly satisfactory, but for an occasional analysis too much time is required to prepare the reagents.
No. 8	0.22	0.23	0.50	0.54	0.50	0.79	0.43	0.48	0.53	0.38	0.39	0.42	0.11	0.37	Methods I and II are good but Method II is preferred because of less danger in loss of alkali through volatilization. Method III is difficult and unsatisfactory.
No. 9	0.19	0.26	0.31	0.57	0.57	0.66	0.47	0.52	0.61	0.41	0.45	0.51	0.22	0.48	Method III is difficult and troublesome.
No. 10	0.23	0.25	0.25	0.58	0.58	0.65	0.42	0.42	0.53	0.47	0.48	0.43	0.18	0.44	Methods I and II give better checks than Method III.
Mean Probable Error[a]	0.24 ±0.020	0.26 ±0.022	0.34 ±0.078	0.57 ±0.041	0.57 ±0.037	0.71 ±0.122	0.45 ±0.015	0.48 ±0.025	0.55 ±0.020	0.42 ±0.040	0.45 ±0.042	0.47 ±0.032	0.13 ±0.026	0.41 ±0.024	Method IV is generally found to be satisfactory, though its purpose is questioned by a few. MgO is not found in the precipitate (nil to 0.01 per cent reported).

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[a] The probable error of a single observation. $\text{P.E.} = \pm 0.674 \sqrt{\frac{\Sigma d^2}{n-1}}$ where Σd^2 is the sum of the squares of the deviations and n is the number of observations.
Average probable error for Method I, ±0.031 for K_2O, ±0.028 for Na_2O, ±0.029 for both.
Average probable error for Method II, ±0.030 for K_2O, ±0.034 for Na_2O, ±0.032 for both.
Average probable error for Method III, ±0.100 for K_2O, ±0.026 for Na_2O, ±0.063 for both.

with total alkali, while Section 9 deals with water-soluble alkali which is discussed below.

The determinations of Na_2O by Method III show a good degree of precision but the results are high as compared with those by Methods I and II. The results by Method III for K_2O are rather erratic. Some of the analysts ran into considerable difficulty with this method and thus acquired a critical attitude towards it. The results were submitted to Mr. Roller of the U. S. Bureau of Mines Experiment Station and he has kindly discussed these results for the benefit of the committee. The Working Committee agrees with him that there are possibilities in his method (Method III), but it is apparent that for many analysts this method, even with clear directions, can be mastered only after some practice. As long as the determination of alkali in portland cement remains an occasional task in most laboratories, the Working Committee feels that the method for alkali should be one that is easy for an analyst of average ability to follow.

Method IV is not in the same class as the other methods. It was included in the investigation because some felt that a determination of water-soluble alkali was needed rather than that of total K_2O and Na_2O in some cases such as the staining of masonry. It is interesting to note that sample L is 1.4 times higher in total alkali than sample K but is 3.2 times higher in water-soluble alkali. Thus it is seen that there is no definite relation between water-soluble alkali and total K_2O and Na_2O except that the former is a fraction of the latter. If it is true, as believed by some, that all K_2O and Na_2O in portland cement is really water soluble, it is important that K_2O and Na_2O be leached out of cement by a uniform method which has been confirmed by practical tests.

Water-soluble alkali is usually reported as Na_2O regardless of any K_2O that may be present. If a sample in fact contains 0.54 per cent of water-soluble K_2O and no water-soluble Na_2O, the result will be reported as 0.44 per cent water-soluble alkali as Na_2O. The error in the assumption of all water-soluble alkali to be Na_2O is probably about 10 per cent in most cases and never exceeds 20 per cent. It is rarely great enough to warrant the time and expense of the separation of K_2O and Na_2O. The method is chiefly applied to masonry cement where a limit of 0.03 per cent water-soluble alkali is imposed. However, if desired, the separation can be effected in accordance with the proposed procedures (see Section 9 (*c*)).[1]

Method IV is a slightly modified form of a method known as the "Treasury Department" method which was received by Universal Atlas Cement Co. from the National Bureau of Standards in November, 1932. After the investigation was started, it was found that the Federal Specification for Masonry Cement (SS-C-181a; May 22, 1936) has a method for water-soluble alkali in Section F-3h. These two methods are in general the same. They are identical as to the manner of leaching alkali out of cement but differ a little in the subsequent treatment of the leaching water. In Method IV, filtrates are evaporated in an alkaline condition, while in the Federal method filtrates are acidified before evaporation. To ascertain whether the differences have any influence on the results, the Federal method was tried in the laboratory of California Portland Cement Co. The analyst made the following report:

"In addition to Method IV, Section F-3h of Federal Specification for Masonry Cement SS-C-181a (May 22, 1936) was tried and a close check was obtained as shown by the following results:

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[1] See p. 745.

	METHOD IV	FEDERAL METHOD
Sample *K*.	0.11 0.11	0.12
Sample *L*.	0.44 0.40	0.40

"The alkali is leached out of cement in exactly the same manner. The differences in the subsequent operations do not seem to make any difference in the results. As far as my heating equipment is concerned, I prefer Method IV, because with it I could carry out my evaporations with more speed and with less attention (precaution against bumping and spattering) than with the other method. However, it is conceivable that with different heating equipment I might prefer the second method."

Method IV has shown a high degree of precision. From the results of a single laboratory and from theoretical considerations, it is safe to say that the same results and degree of precision would be obtained with the Federal method. Since the Federal method has been in use for more than a year, we believe that we should not adopt a method for water-soluble alkali which differs from the Federal method for total alkali to any greater extent than is necessary. Method IV is recommended as a tentative method for the determination of water-soluble alkali which is incorporated as Section 9 of the proposed procedures appended to this report.[1]

The thanks of the Working Committee and the Society are due each one of those who generously cooperated in the investigation of methods for alkali. The indebtedness of the Working Committee cannot be emphasized too much, for the work required a great deal of time and caused much inconvenience. The assistance given by G. E. F. Lundell and P. S. Roller through helpful suggestions in the improvement of the methods is also much appreciated. Acknowledgment is made also to the following laboratories:

Cooperating Laboratories:

U. S. Bureau of Reclamation, Denver, Colo. R. F. Walter, Chief Engineer.
Idaho Portland Cement Co. W. R. Chandler, Chief Chemist.
Coplay Cement Manufacturing Co. M. E. Grunewald, Chief Engineer.
Portland Cement Assn. H. F. Gonnerman, Manager of Laboratory.
Tennessee Valley Authority. P. J. Freeman, Principal Materials Engineer.
Edison Cement Corp. G. C. Wilsnack, Chemical Engineer.
Universal Atlas Cement Co. T. A. Hicks, General Chemist.
California Division of Highways. T. E. Stanton, Materials and Research Engineer.
Kansas State College. W. A. Van Winkle, Professor of Chemistry.
California Portland Cement Co. O. D. Guire, Jr., Analyst.
NOTE.—The order of laboratories does not correspond to the tabulation of results.

Rapid Methods for Magnesia:

The Acid-Alkali Method for Rapid Determination of Magnesia and the Method for the Rapid Determination of Magnesia by Titration of Magnesium Oxyquinolate (Sections 1, 2, 3, and 4 of Tentative Methods C 114 – 37 T) have been in use as tentative methods for two years. The Working Committee has solicited criticisms of these methods but has received none. It is recommended that they be advanced to standard with the following two changes: (*1*) Rewrite the text in the imperative form which is now used for Standard Methods C 77 – 37, and (*2*) Insert a note stating that either method may be used when magnesia alone is to be determined but that in cases of dispute the results obtained according to Section 16 of Standard Methods C 77 – 37 shall govern.

Methods for Manganic Oxide and Phosphorus Pentoxide:

In February, 1937, the Working Committee reported the results of a coopera-

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[1] See p. 745.

TABLE II.—ANALYTICAL DATA FROM COOPERATIVE INVESTIGATION OF METHODS FOR THE DETERMINATION OF MANGANIC OXIDE AND PHOSPHORUS PENTOXIDE IN PORTLAND CEMENT.

Samples G, H(I), and J(M) are portland cements for general use. The brands are well known and were selected in order to have a sample high in Mn_2O_3, one high in P_2O_5 and one approximately of the average composition of American cements.

Method I, for Mn_2O_3: The manganese in the solution of cement is oxidized to permanganic acid with sodium bismuthate and then titrated with sodium arsenite. (Tentative Methods C 114 - 37 T, Sections 7 and 8.)

Method II, for Mn_2O_3: The solution of cement is neutralized with zinc oxide and then titrated with potassium permanganate. (Ford's Modification of Volhard procedure.)

Method III, for P_2O_5: The phosphorus in the solution of cement is precipitated as ammonium phosphomolybdate and then re-precipitated as magnesium ammonium phosphate. (Tentative Methods C 114 - 37 T, Sections 5 and 6.)

Method IV, for P_2O_5: The phosphorus in the solution of cement is precipitated as ammonium phosphomolybdate and then titrated with standard alkali. (Van Winkle method.)

Laboratory	Manganic Oxide, Mn_2O_3					Phosphorus Pentoxide, P_2O_5							
	Sample G	Sample H(I)		Sample J(M)		Sample G		Sample H(I)			Sample J(M)		
	Method I	Method I	Method II	Method I	Method II	Method III[a]	Method III[b]	Method III[a]	Method III[b]	Method IV	Method III[a]	Method III[b]	Method IV
No. 1	0.11	0.85	0.85	0.06	0.08	0.17	....	0.08	....	0.01	0.69	....	0.68
No. 2	0.11	0.87	0.82	0.07	0.06	0.16	0.12	0.08	0.04	0.05	0.72	0.68	1.03
No. 3	0.10	0.86	0.84	0.06	0.07	0.14	0.11	0.03	Nil	0.05	0.68	0.65	0.73
No. 4	0.10	0.85	0.84	0.07	0.07	0.07	0.05	0.04	0.02	0.02	0.65	0.63	0.80
No. 5	0.11	0.99	0.86	0.07	0.09	0.13	....	0.01	....	0.02	0.66	....	0.70
No. 6	0.10	0.87	0.88	0.06	0.05	0.11	0.10	0.01	Nil	0.04	0.61	0.60	0.79
No. 7	0.11	0.85	0.81	0.07	0.07	0.14	....	0.04	....	Nil	0.64	....	0.85
No. 8	0.10	0.85	0.80	0.06	0.13	0.11	0.07	0.04	Nil	0.04	0.69	0.65	1.17
No. 9	0.12	0.89	....	0.08	....	0.11	0.11	0.02	0.02	....	0.65	0.65	....
No. 10	....	....	0.88	....	0.10	....	....	....	....	0.06	....	....	0.65
Mean	0.11	0.88[c]	0.84	0.07	0.08	0.13	0.09	0.04	0.01	0.03	0.67	0.64	0.82
Probable Error[d]	±0.005	±0.031[c]	±0.017	±0.005	±0.015	±0.021	±0.019	±0.018	±0.011	±0.014	±0.022	±0.019	±0.112

[a] Not corrected for blank.

[b] Corrected for blank.

[c] The mean and probable error are 0.86 and ±0.010 respectively if the determination by laboratory No. 5 is rejected as being doubtful.

[d] The Probable Error of a Single Observation. P.E. = $\pm 0.674 \sqrt{\frac{\Sigma d^2}{n-1}}$ where Σd^2 is the sum of the squares of the deviations and n is the number of observations.

tive investigation of a method for the determination of manganic oxide (Mn_2O_3) and a method for phosphorus pentoxide (P_2O_5) in portland cement. The results showed the methods to be satisfactory and, as recommended by the Working Committee, they were adopted as Tentative Methods C 114 – 37 T, (Sections 5, 6, 7, and 8). However, it was pointed out that there were other methods which would require less time but yet give equally accurate results. C. L. Ford suggested his modification of a method for manganic oxide.[1] W. A. Van Winkle of Kansas State College of Agriculture and Applied Science recommended a volumetric method for phosphorus pentoxide which he has often used.

The cooperating laboratories were asked to assist further in trying these two methods. The results of the two series are shown in Table II.

In considering the determination of manganic oxide by Method I (the present tentative method) one is impressed by the closeness with which the analysts checked each other with the single exception of the determination of manganic oxide in sample H by laboratory No. 5. It is apparent that this exception was due to some error which could not be attributed to the method. Though some analysts found the end point in Method II (Ford's method for Mn_2O_3) somewhat uncertain and the probable errors show Method II to be less precise than Method I, good results were obtained with Method II. The committee believes that Method II can be used as an A.S.T.M. alternate method because of its advantage in speed and simplicity. It requires from 30 to 60 min., while the present tentative method requires 2 or 3 hr. G. E. F. Lundell has expressed his belief to the Working Committee "that the zinc oxide - permanganate method (such as Method II, Ford's Method) for the determination of manganese in cement is suitable for routine examinations of cement, but that it should not be recommended as a referee method for use in umpire determinations of manganese."

The Working Committee recommends the acceptance of Method II as a tentative alternate method for the determination of manganic oxide in portland cement and also the continuation of the present tentative methods for manganic oxide (C 114 – 37 T, Sections 7 and 8) as such. Method II has been revised since the experiments in accordance with O. A. Ellingson's (Universal Atlas Cement Co.) suggestion that the solution be kept hot during the titration.

The data in the table show that Method IV (Van Winkle's method for P_2O_5) is satisfactory where the content of phosphorus pentoxide is low but not where the content is high as in sample J(M). It appears that this method in its present form is not suitable as a substitute for the present tentative method for phosphorus pentoxide (Tentative Methods C 114 – 37 T, Sections 5 and 6, Method III), or even as an alternate method. (A copy of Method IV can be obtained by applying to J. R. Dwyer, Technical Assistant of Committee C-1).[2] Sections 5 and 6 of Tentative Methods C 114 – 37 T should be continued as a tentative method for phosphorus pentoxide pending further study.

The tentative methods for phosphorus pentoxide (Tentative Methods C 114 - 37 T, Sections 5 and 6) is tedious, and a quicker method would be of advantage if accurate enough. At the request of the Working Committee, O. A. Ellingson, Chief Chemist of the Duluth plant of Universal Atlas Cement Co., went fully into the problem of a quick determination of phosphorus pentoxide in cement. In order to establish the best conditions for the precipitation of phosphorus as phosphomolybdate which is then titrated with standard alkali, he made about 50 determinations, varying the several factors which might affect the precipitation. He has worked out a method which is similar to Method IV (Van Winkle's method) in a general way but different in some details. He gave the matter so much thought that we have great hopes that his method will prove satisfactory in other analysts' hands. We propose to ask a number of cooperating laboratories to test Mr. Ellingson's method.

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[1] Ford's method is a modification of one described on page 1612 of Scott's "Standard Methods of Chemical Analysis," Fourth Edition.

[2] National Bureau of Standards, Washington, D. C.

The names of those who assisted us in the study of the problem of the determination of manganic oxide and phosphorus pentoxide in cement are given in the list below. The thanks of the Working Committee and the society are due them. Messrs. Van Winkle and Ellingson deserve special mention.

Cooperating Laboratories:

- California Portland Cement Co., O. D. Guire, Jr., Analyst.
- Idaho Portland Cement Co., W. R. Chandler, Chief Chemist.
- Kansas State College of Agriculture and Applied Science, W. A. Van Winkle, Professor of Chemistry.
- Monolith Portland Cement Co., O. C. Hart, Chief Chemist.
- National Bureau of Standards, Division V-4, G. E. F. Lundell, Chief.
- Portland Cement Assn., H. F. Gonnerman, Manager of Laboratory.
- Riverside Cement Co., T. F. Mullan, Chief Chemist.
- Tennessee Valley Authority, P. J. Freeman, Principal Materials Engineer.
- Universal Atlas Cement Co., Buffington Plant, T. A. Hicks, General Chemist, D. I. Elder, Research Chemist.
- Universal Atlas Cement Co., Duluth Plant, T. A. Hicks, General Chemist, O. A. Ellingson, Chief Chemist.

NOTE.—The order of laboratories does not correspond to the tabulation of results.

Methods for Free Lime:

A report of the Working Committee to Committee C-1 in the latter part of 1937 contained a program for the investigation of methods for the determination of free lime in portland cement. This investigation was started shortly thereafter. Forty-five laboratories have agreed to make free lime tests for the Working Committee.[1] One of them is the British Building Research Station, which has given a great deal of thought to the problem. The generous assistance of the cooperating laboratories is indeed appreciated.

To date about one-third of the laboratories have reported their results. Results and comments that have been received show that this investigation is greatly needed and will contribute much to the free lime problem.

Methods for Determination of Silica:

Some time ago Chairman Bates, through J. R. Dwyer, called the committee's attention to Bureau of Standards *Research Paper 891*, "A Rapid Method for the Determination of Silica in Portland Cement," by Edwin E. Maczkowski. T. A. Hicks had this method (commonly known as the ammonium chloride method) tested at two plant laboratories of Universal Atlas Cement Co. The conclusion was that if a rapid method was desired for the determination of silica, the well-known and commonly used perchloric acid method would be preferable. This opinion was questioned by some cement chemists. The method was tried in the laboratory of California Portland Cement Co. along with a perchloric acid method. The analyst found the ammonium chloride method as easy to carry out as the perchloric acid method. His results with one sample of cement are as follows, some earlier work being listed for comparison:

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[1] A subsequent report on this subject entitled, "Cooperative Study of Methods of Determining Free Lime in Portland Cement and Clinker," presented by W. C. Hanna, T. A. Hicks, and G. A. Saeger, on behalf of the Working Committee was published in the ASTM BULLETIN, No. 94, October, 1938, p. 47.

Method	SiO_2 not Corrected for Impurities	SiO_2 Corrected for Impurities, (HF Treatment)
Perchloric acid method		
First day	21.02 20.98	20.88 20.86
Second day	21.08 21.06	20.92 20.94
Ammonium chloride method		
First day	21.38 21.42	21.24 21.28
Second day	21.40 21.48	21.28 21.36
Average for perchloric acid method	21.04	20.90
Average for ammonium chloride method	21.42	21.29
A.S.T.M. Standard Methods C 77 - 37, average of ten laboratories	.....	21.16
Perchloric acid method, average of ten laboratories	.....	21.01
National Bureau of Standards	.....	21.20

The sample used is designated by the Working Committee as A.S.T.M. Standard Cement Sample *A* which was used with three other samples in the first investigation (1933–1934), the purpose of which was to select methods for the determination of silica, alumina, ferric oxide, lime, and magnesia. Ten laboratories took part in the investigation. The averages of silica determinations by a method employing double evaporation in hydrochloric acid method (Standard Methods C 77 - 37, Section 11) and a perchloric acid method are given in the above table. Under G. E. F. Lundell's supervision, the National Bureau of Standards made an accurate analysis of the sample, using their own methods. Their silica determination, which is included in the table, was made by a procedure which involved double evaporation in hydrochloric acid and the recovery of silica (0.03 per cent in this particular case) in the main precipitate of alumina and ferric oxide.

The meager results seem to show that there are possibilities in the ammonium chloride method and that it may be as good as the perchloric acid method where quick results are required.

Alternate Methods:

The present standard method for the analysis of cement is tedious for some of the components. There is a demand for quicker methods. The Government and other political groups are usually under a legal obligation to use specified methods regardless of the cost in labor and equipment. It stands to reason that it is advantageous to all concerned to keep the cost of testing as low as possible within reason. This reopens the question as to whether there should be alternate methods for silica and lime.

The single precipitation of lime as calcium oxalate followed by titration with potassium permanganate and the single precipitation of magnesia as phosphate are universally practiced. If it is considered worth while to have alternate methods for the quick determination of silica, lime, and magnesia, the Working Committee will study the matter and have some methods tested.

For the rapid determination of silica it may be difficult to decide between the perchloric acid method and the ammonium chloride method without cooperative tests. It is also necessary to consider the effect of any method for silica on the determination of alumina, and thus actual tests in the form of determinations of both silica and "R_2O_3" (alumina and ferric oxide) are necessary for an adequate study.

It is to be understood in the discussion of alternate methods that they are primarily for routine examinations of cement and are not to be used as a basis of rejection or settlement of dispute. The Working Committee will be glad to receive comments on such methods.

Respectfully submitted on behalf of the Working Committee,

W. C. HANNA,
Chairman.

REPORT ON INVESTIGATION OF PEBBLE MORTARS BY FOURTEEN LABORATORIES

Sponsored by Working Committee on Plastic Mortar Tests

The Working Committee on Plastic Mortar Tests outlined in its report last year[1] on a series of cooperative tests of certain pebble mortar mixes suggested by Mr. P. H. Bates and by Mr. J. C. Pearson. The committee is now prepared to report on these tests.

Purpose:

The purpose of the investigation was to determine whether the pebble mortars are better than the mortar specified in Method C 109[2] in regard to plasticity, water retention, air voids and strength uniformity and whether they are suitable for use with a standard consistency.

The C 109 mortar does not retain the mixing water very well, it has relatively high air voids, and is a wet mortar rather than a plastic one. These properties are due in large part to the lack of proper grading of the sand and to its small maximum size together with the specified proportions of cement and sand. The usual practise to improve these properties is to increase the cement content but in this case proportions of about one part cement to one and one-quarter parts of the sand by weight were required to produce what is generally considered a good mortar. Rich mixtures such as this would be are not satisfactory for the purpose from other standpoints such as the narrow range of molding consistency which would require a standardized consistency and a more accurate means of measuring it than is now available and because the strength results are more sensitive to small variations in the testing procedure.

In addition to the lack of proper grading of the sand, the grading is subject to variations within the limits of the method which probably affects uniformity of strength results, and differences in the fineness of cement may have a similar effect. The sand is ideal from the standpoint of absorption.

Tentative Method C 109 – 37 T specifies a given proportion of the cement and of the graded Ottawa sand and a fixed water-cement ratio which allows the consistency to vary to whatever extent it is affected by the cement, by variations in the grading of the sand, and by laboratory conditions. Usually the consistency falls within a range suitable for molding the cubes but occasionally it does not so that the operator must change the water-cement ratio specified or use an unworkable consistency. If the consistency were standardized and the proportions or water-cement ratio made variable to produce a given consistency this difficulty would be eliminated, but all methods of measuring consistency so far tried with the C 109 mortar lack sufficient uniformity between laboratories to offer any improvement over the present method of test.

A low-absorptive sand of larger maximum size and a grading which would produce a mortar of better plasticity, greater water retention, and lower air voids would seem to offer the most promising possibilities of improvement of these properties.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 282 (1937).

[2] Tentative Method of Test for Compressive Strength of Portland-Cement Mortars (C 109 – 37 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 726 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 459.

Messrs. Bates and Pearson, working independently along these lines, arrived at mixes similar as to maximum size of aggregate, gap gradings, and cement-water ratio. The basic mixes suggested together with C 109 mix are as follows, the proportions given being for a 6-cube batch:

	BATES MIX	PEARSON MIX	C 109 MIX
Low-absorptive gravel ($\frac{3}{8}$ in. to No. 4), g. .	1350	1250	0
Standard Ottawa sand (Nos. 20–30), g.	790	520	0
C 109 sand, g.	0	0	1300
Ottawa banding sand, g.	0	315	0
Potter's flint, g.	110	0	0
Cement, g.	450	375	470
C/W (cement-water ratio) by weight.	1.88	1.88	1.88
W/C (water-cement ratio) by volume . . .	0.8	0.8	0.8
Water, ml.	239	200	250

Mr. Bates placed greatest emphasis upon consistency, reasoning that a truly plastic consistency such as is used in molding pottery should prove satisfactory. He suggested for the smallest fraction of the aggregate a very fine material such as potter's flint. Mr. Pearson stressed the importance of low-absorptive aggregate and the maintaining of workability within a given range as determined by the slump test and maintained within the range by changing the cement paste content if necessary.

In order to place the two mortars on a basis for comparison in these tests, Mr. Bates accepted the slump test method of Mr. Pearson and reduced the portion of potter's flint, thus sacrificing considerable plasticity, which he considers important.

Materials:

The low-absorptive (0.4 per cent) pebbles were purchased from a quarry, suggested by Mr. Pearson, in Columbia, S. C. at a cost of $1.00 per 100 lb. f.o.b. quarry and shipped direct to the laboratories. The potter's flint and the banding sand, each costing $1.00 per 100 lb. f.o.b. quarry, were purchased from a quarry in Ottawa, Ill., and distributed by one of the participating laboratories. The standard and the graded Ottawa sand were furnished by each laboratory from its own supply. The cost of these two materials respectively is $3.25 and $2.25 per 100 lb. f.o.b. Ottawa, Ill. The cements were donated, proportioned, and distributed direct to the laboratories by the manufacturers.

The following laboratories participated in the investigation:

NAME	INDIVIDUAL
Ash Grove Lime & Portland Cement Co., Chanute, Kans.	Guy O. Gardner
California Portland Cement Co., Colton, Calif.	W. C. Hanna
Froehling & Robertson, Inc., Richmond, Va. . . .	G. J. Durant
Illinois State, Division of Highways, Springfield, Ill.	V. L. Glover
Lehigh Portland Cement Co., Allentown, Pa. . . .	J. C. Pearson
Lone Star Cement Corp., Hudson, N. Y.	M. A. Swayze
Metropolitan Water District of Southern California, Banning, Calif. .	Lewis H. Tuthill
Missouri State Highway Department, Jefferson City, Mo.	F. V. Reagel
National Bureau of Standards, Washington, D. C.	P. H. Bates
Portland Cement Association, Chicago, Ill.	H. F. Gonnerman
Tennessee Valley Authority, Knoxville, Tenn. . .	P. J. Freeman
U. S. Bureau of Public Roads, Washington, D. C.	F. H. Jackson
Universal Atlas Cement Co., Chicago, Ill.	O. L. Moore
Washington, State of, Department of Highways, Olympia, Wash.	Bailey Tremper

Description of Tests:

Compressive strength and workability tests were made with the Bates, Pearson and C 109 mixes by fourteen laboratories using three cements, a standard, a high-early-strength, and a moderate-heat portland cement. Test specimens for compressive strength were 2-in. cubes, three for each period, and the test periods 1, 3, 7, and 28 days. The entire program was repeated two additional times, making a total of three complete rounds of tests. The pebble mortars were made to slump within a range of $1\frac{5}{8}$ to $2\frac{3}{8}$ in., as specified by Mr. Pearson, by adding to or deducting from the basic mixes, when necessary, cement and water in the ratio of 1.88 by weight (water-cement ratio 0.8 by volume). The slump test was the same as A.S.T.M. Method D 138 – 32 T[1] except that the cone was one-half size (2 by 4 by 6 in.), was filled in two layers and rodded with a $\frac{3}{8}$-in. bullet-pointed rod. All other methods of test in the case of the pebble mortars and all tests in the case of the C 109 mortar were made in accordance with A.S.T.M. Method C 109 – 37 T. The slump test was made on the first batch in each round in order to regulate and obtain the specified slump. On the second batch of each round flow tests were made for record using (*a*) the Burmister flow trough[2] as modified by Lewis H. Tuthill,[3] and (*b*) the 10-in. flow table (A.S.T.M. C 91 – 32 T, masonry cement[4]). All laboratories followed the procedure as described except that laboratory No. 2, due to an error in copying the table of the basic mixes, added 110 g. of banding sand to the Bates mix throughout.

The modification of the Burmister trough was as follows: The dimensions of the trough were one-half those of the larger Burmister trough. It was mounted on a block of wood 4 by 4 by 15 in. by means of trunnions on the back of the trough and supports attached to the block. The open end of the trough was lifted 1 in. and dropped by means of a cam and crank attached to the block.

The three cements were tested also in accordance with A.S.T.M. Methods C 77 – 37,[5] C 115 – 34 T (specific surface),[6] and C 114 – 37 T (chemical analysis).[7]

Discussion of Results:

For convenience in discussing the test results, the Bates, Pearson, and C 109 mortars will be referred to in the following discussion as the B, P, and C mortars respectively.

In Table I the compressive strength results are summarized and the percentage mean variations between the laboratories given. The test results of laboratory No. 2 for the B mortar, which contained additional sand as explained previously, are considered as normal in the following studies. There is some evidence that the later strengths were increased slightly, but the effect is negligible. The compressive strengths obtained with the B and P mortars are about the same order, the B mortar giving slightly higher results, the differences being 4.6 per cent at 1 day, 3.7 per cent at 3 days, 2.7 per cent at 7 days, 1.6 per cent at 28 days, and 3.15 per cent for the four periods. The strengths of the pebble mortars are decidedly higher than the strengths of the C mortar, the average of the pebble mortar strengths being 62 per cent higher than those of

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[1] Tentative Method of Test for Consistency of Portland-Cement Concrete (D 138 – 32 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 775 (1932); also 1937 Book of A.S.T.M. Tentative Standards, p. 847.

[2] Donald M. Burmister, "The Concrete Flow Trough," *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part II, p. 554 (1931).

[3] Testing Engineer, The Metropolitan Water District of Southern California, Banning, Calif.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 695; also 1937 Book of A.S.T.M. Tentative Standards, p. 445.

[5] Standard Methods of Sampling and Testing Portland Cement (C 77 – 37), 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

[6] Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 – 34 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 777; also 1937 Book of A.S.T.M. Tentative Standards, p. 466.

[7] Tentative Method of Chemical Analysis of Portland Cement (C 114 – 37 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 717; also 1937 Book of A.S.T.M. Tentative Standards, p. 450.

TABLE I.—COMPRESSIVE STRENGTH OF 2-IN. CUBES, LB. PER SQ. IN.

Each value is average of nine cubes, three each made on different days.

Laboratory	1 Day			3 Days			7 Days			28 Days		
	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix
CEMENT NO. 1												
No. 1	743	639	298	2283	2106	1342	4178	3941	2558	6911	6905	4961
No. 2[a]	703	645	250	2564	2221	1330	5061	4700	2791	8194	7625	4785
No. 3	862	711	406	3139	2841	1754	4882	4818	3013	8121	7733	5213
No. 4	690	628	264	2568	2429	1213	4466	4364	2270	7282	7193	3960
No. 5	711	635	303	2365	2199	1388	4129	4077	2618	6904	6975	4761
No. 6	716	658	362	2399	2135	1267	4274	4104	2343	7152	7009	4248
No. 7	860	760	425	2525	2435	1620	4340	4130	2885	7185	7405	5250
No. 8	762	699	338	2346	2228	1405	4419	4251	2675	7147	6950	4529
No. 9	687	617	350	2450	2267	1403	4413	4223	2553	7400	6813	4730
No. 10	590	540	270	2220	2220	1290	4120	3610	2360	7170	6770	4640
No. 11	745	734	349	2408	2216	1364	4228	4198	2601	6861	7203	4436
No. 12	686	608	286	2120	2067	1111	3977	3692	2272	6687	6343	4056
No. 13	801	776	485	2556	2411	1537	3921	3958	2728	6896	6686	4646
No. 14	846	679	404	2506	2306	1614	4290	4009	3029	7317	6545	4976
Average	743	666	342	2461	2292	1403	4336	4148	2621	7230	7011	4656
Percentage mean variation	8.1	7.7	16.1	6.4	6.0	9.3	5.2	5.7	7.6	4.3	4.3	6.4
CEMENT NO. 2												
No. 1	2789	2778	1897	5539	5028	3633	6522	6536	4694	7539	8158	6234
No. 2[a]	3278	3081	1895	5772	5691	3561	6667	6736	4750	8361	8222	5508
No. 3	3118	3007	1944	5632	5694	3730	6854	6667	4429	8054	8048	5980
No. 4	2936	2925	1749	5236	5166	3346	6408	6423	4147	7782	7781	5042
No. 5	2502	2468	1786	4779	4788	3477	5999	5963	4593	7265	7360	5682
No. 6	2793	2681	1873	4820	4745	3390	5833	5749	3960	6902	6977	5032
No. 7	2985	3125	2215	5030	5065	3745	6160	6185	4675	7735	7555	5925
No. 8	2525	2445	1820	4657	4588	3411	5845	5993	4307	7087	7346	5463
No. 9	2643	2687	1803	4837	4950	3510	6200	6360	4487	7543	7850	5627
No. 10	2720	2680	1690	5010	4820	3370	6390	6130	4180	7670	7620	5450
No. 11	2723	2795	1816	5028	5015	3378	6021	6119	4069	7283	7550	5069
No. 12	3127	2936	1995	4765	4733	3244	5479	5558	3914	6489	6989	4940
No. 13	2678	2773	1910	4764	4786	3509	5688	6011	4335	7263	7489	5442
No. 14	3119	2935	2337	5199	4889	4113	6384	6095	5010	7562	7404	6272
Average	2852	2808	1909	5076	4997	3530	6175	6180	4396	7467	7596	5548
Percentage mean variation	7.2	5.9	6.4	5.6	4.8	4.6	5.1	4.2	6.1	4.8	4.0	6.3
CEMENT NO. 3												
No. 1	975	842	510	2122	1959	1314	3247	3164	2017	6386	6011	4208
No. 2[a]	1075	995	478	2314	2128	1200	4158	3822	2250	6503	6639	3833
No. 3	1202	1137	610	2815	2761	1661	4077	3934	2459	6870	6727	4523
No. 4	1181	999	549	2420	2177	1254	3527	3340	1960	6428	5868	3681
No. 5	1071	970	528	2334	2287	1402	3588	3417	2281	6261	6200	4136
No. 6	1080	1023	565	2304	2130	1326	3436	3172	1923	6116	5472	3370
No. 7	1290	1265	755	2405	2300	1605	3675	3570	2410	6370	6190	4205
No. 8	961	988	542	2087	2344	1113	3374	3687	1925	6242	6572	3517
No. 9	1050	963	587	2343	2217	1373	3633	3387	2107	6510	6187	3977
No. 10	940	900	550	2260	2180	1360	3420	3230	1980	6040	5750	3670
No. 11	1172	1063	595	2426	2241	1433	3723	3372	2216	6261	6114	3905
No. 12	1056	920	462	2336	2247	1288	3596	3388	2043	6370	5999	3864
No. 13	1251	1092	733	2535	2335	1579	3640	3523	2440	6367	5844	4254
No. 14	1146	1094	750	2380	2257	1612	3820	3479	2578	6261	6112	4655
Average	1103	1018	587	2364	2254	1394	3637	3463	2185	6356	6120	3985
Percentage mean variation	8.0	7.9	12.4	4.9	4.8	9.5	5.0	5.1	8.7	2.2	4.2	6.4

[a] Added 110 g. banding sand to Bates mix.

the C mortar at 1 day, 53 per cent at 3 days, 52 per cent at 7 days, 47 per cent at 28 days, and 53.5 per cent for the four periods. These results are quite unusual since the cement-water ratios used were identical. It is not the purpose of this investigation to attempt to explain these differences in strength, but, in passing, the differences in air voids of the mortars and the theories of C. A. G.

TABLE II.—PERCENTAGE MEAN VARIATION IN COMPRESSIVE STRENGTH OF THREE TESTS FROM THEIR AVERAGE.

Tests Made on Three Days.

Laboratory	1 Day			3 Days			7 Days			28 Days		
	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix
CEMENT NO. 1												
No. 1......	0.9	9.9	5.0	7.3	8.3	6.2	2.3	2.4	1.5	4.5	4.1	0.8
No. 2[a].....	2.6	5.4	0.0	0.8	5.4	2.6	2.4	3.2	1.4	0.9	3.3	0.8
No. 3......	1.0	5.6	2.2	3.6	1.0	1.4	5.0	1.3	2.1	0.8	3.5	3.0
No. 4......	21.0	18.7	17.3	5.2	3.1	0.5	3.6	2.5	2.2	2.1	2.1	0.9
No. 5......	4.3	1.8	6.4	2.1	1.7	2.3	5.2	1.3	3.5	1.0	3.2	5.5
No. 6......	4.9	4.9	4.7	3.6	3.2	4.8	0.5	1.8	1.5	2.4	2.2	3.3
No. 7......	11.4	11.4	7.5	5.0	4.7	3.0	4.9	4.6	2.8	2.3	5.5	3.6
No. 8......	13.9	8.4	13.3	3.8	3.6	3.2	4.4	3.2	3.3	2.4	2.6	2.4
No. 9......	1.6	4.7	1.9	3.0	2.5	0.3	3.0	2.7	2.7	0.5	3.7	1.5
No. 10......	4.5	5.6	3.7	5.4	1.0	3.3	2.7	2.5	2.3	2.6	1.4	2.7
No. 11......	1.6	8.4	5.2	8.8	12.1	7.2	4.4	2.8	5.6	1.5	4.4	7.6
No. 12......	6.0	2.8	2.6	3.8	9.3	9.9	2.4	2.0	3.8	1.9	6.4	3.3
No. 13......	4.9	5.9	9.3	3.4	2.0	4.9	5.3	2.5	7.1	1.2	8.0	4.9
No. 14......	2.7	1.1	5.4	1.1	4.1	0.4	1.9	4.3	2.1	3.0	1.4	1.2
Average.....	5.8	6.8	6.0	4.1	4.4	3.6	3.4	2.6	3.0	1.9	3.7	3.0
CEMENT NO. 2												
No. 1......	3.1	2.5	1.6	12.4	1.6	1.1	13.3	3.8	3.2	0.2	2.4	1.4
No. 2[a].....	4.3	3.0	0.7	2.3	1.6	0.1	3.3	1.9	2.8	2.2	0.9	3.6
No. 3......	1.4	2.4	4.2	2.6	4.4	2.9	2.7	0.6	2.0	0.6	1.7	0.8
No. 4......	2.2	3.3	3.3	3.4	1.6	6.1	3.1	2.5	2.7	3.8	3.8	1.4
No. 5......	1.5	2.4	2.8	0.4	2.8	1.5	2.1	3.2	2.7	1.7	2.5	0.8
No. 6......	1.2	0.7	3.1	1.8	3.9	0.6	4.4	3.6	3.2	3.7	1.8	3.6
No. 7......	6.7	4.8	7.4	2.9	3.7	1.5	2.9	3.8	1.2	1.5	3.5	1.5
No. 8......	3.5	3.7	4.4	1.4	2.3	2.0	3.1	1.4	2.5	3.9	2.4	3.4
No. 9......	0.4	1.9	1.3	0.9	2.4	1.1	2.5	0.8	2.2	2.7	0.5	1.3
No. 10......	1.4	1.0	2.0	5.9	3.2	5.4	1.8	2.6	1.2	0.3	0.5	0.9
No. 11......	2.1	1.3	0.6	1.8	5.8	2.5	1.7	3.6	1.4	0.2	2.8	2.2
No. 12......	0.7	0.5	4.7	0.5	1.4	1.5	1.7	2.5	1.4	1.1	0.2	4.4
No. 13......	8.1	1.9	2.9	1.5	4.5	0.6	2.3	3.3	2.8	5.0	2.4	2.1
No. 14......	4.2	4.2	6.6	1.2	4.2	2.0	0.5	2.1	1.9	2.2	2.4	1.1
Average.....	2.9	2.4	3.3	2.8	3.1	2.1	3.2	2.5	2.2	2.1	2.0	2.0
CEMENT NO. 3												
No. 1......	8.5	11.2	6.3	2.4	3.7	4.4	5.2	1.8	2.8	2.1	2.5	1.3
No. 2[a].....	1.5	4.9	0.8	4.2	1.5	3.7	1.2	2.1	3.9	1.2	1.0	3.6
No. 3......	6.1	2.5	2.5	3.6	1.7	4.3	1.7	3.9	2.6	1.1	2.0	0.8
No. 4......	6.9	1.8	1.9	3.4	4.2	0.4	3.1	3.4	3.2	4.2	2.8	4.6
No. 5......	0.9	1.1	2.2	3.2	2.5	1.4	0.9	3.1	3.8	2.1	1.7	2.5
No. 6......	2.4	2.2	1.2	0.6	2.6	2.7	1.0	0.7	2.8	1.7	1.3	1.3
No. 7......	9.3	9.3	12.8	3.7	5.3	4.0	2.9	4.5	1.7	1.5	2.4	3.2
No. 8......	1.0	1.6	3.4	1.5	3.0	3.8	1.6	2.8	0.5	1.2	2.3	3.0
No. 9......	3.8	2.3	0.7	2.2	1.1	1.8	2.0	3.6	0.4	1.6	1.4	0.6
No. 10......	2.5	5.2	3.3	5.0	2.1	2.2	2.5	2.0	0.8	2.1	1.3	3.9
No. 11......	4.3	2.5	4.8	2.6	2.9	2.6	1.8	3.7	1.3	0.9	1.9	1.8
No. 12......	4.7	5.5	6.7	2.7	2.1	6.0	0.8	1.4	1.0	1.7	1.7	1.9
No. 13......	9.8	3.0	4.4	3.4	1.8	4.4	1.0	2.4	3.6	1.7	7.3	1.8
No. 14......	3.9	3.4	4.5	3.2	2.0	1.6	1.5	2.3	3.2	0.7	2.2	4.1
Average.....	4.7	4.0	4.0	3.0	2.6	3.1	1.9	2.7	2.3	1.7	2.3	2.5

[a] Added 110 g. banding sand to Bates mix.

Weymouth,[1] C. C. Furnas,[2] and F. O. Anderegg[3] are offered as possible explanations. In this connection, laboratory No. 4 made tests using materials similar to these, the same cement-water ratio, and a continuous grading from No. 100 to $\frac{3}{8}$-in. (five fractions) in accordance with Weymouth's theory, and obtained strengths of the same order.

The uniformity of the strength results of the three mortars between laboratories as expressed by percentage mean variation from the average is better for the pebble mortars than for the C mortar. The average figure for the P mortar is 5.4 per cent, for the B mortar 5.6 per cent, and for the C mortar 8.3 per cent. The latter figure compares with 5.7 per cent obtained in the series reported in 1934.[4] The average figure for the tensile strengths in the present series is 6.6 per cent and in the 1934 series 3.8 per cent. The two series of tests are not quite comparable in the following respects. The sand for the present C series came from the stock of each laboratory and the tests were repeated three times. The sand for the 1934 series was a single lot distributed by one of the laboratories, the grading was not quite the same as now required by the C 109 method, and the tests were repeated four times.

The briquet tests in the present series were not repeated on different days except by one or two laboratories while in the 1934 series all of the laboratories repeated the tests four times.

In the following table of percentage mean variations in strength results the figures of the present series are added to the table appearing in the 1934 report:

Specimen	Test Series	Number of Laboratories	Percentage Mean Variation in Strength Results				
			1 Day	3 Days	7 Days	28 Days	Average
Briquets	1929 Report	7	10.4[a]	7.3[b]	6.5	6.1	7.6
	1930 Report	10	11.3	5.5	4.5	4.0	6.3
	1934 Report	10	5.6	3.5	2.9	3.0	3.8
	Present Report[c]	14	9.0	6.0	6.8	4.6	6.6
Cubes, Graded Ottawa Sand	1929 Report	7	14.6[a]	10.1[b]	11.3	9.1	11.3
	1930 Report	10	10.1	7.9	7.1	8.3	8.4
	1934 Report	10	9.7	4.2	4.2	4.5	5.7
	Present Report	14	11.6	7.8	7.5	6.4	8.3
Pebble Mortars B	Present Report	14	7.8	5.6	5.1	3.8	5.6
Pebble Mortars P	Present Report	14	7.2	5.2	5.0	4.2	5.4

[a] 2 Days.
[b] 4 Days.
[c] Tests not repeated on different days.

In Table II the percentage mean variations of compressive strength results of three tests, or rounds, by each laboratory are given, showing how consistently each laboratory checked itself in three tests. The variation for all laboratories, periods and cements is 3.1 per cent for the B, 3.1 per cent for the C, and 3.3 per cent for the P mortar.

In Table III are given the percentage mean variations of compressive strength results of three test specimens broken at a period, averaged for three rounds of tests. The averages for all laboratories, periods and cements are 2.2 per cent for the B, 2.2 per cent for the C, and 2.3 per cent for the P mortar.

In Table IV the percentage mean variations of Tables I, II, and III are summarized. The average figures for the three types of variation are 3.6 per cent for the B, 3.7 per cent for the P, and 4.5 per cent for the C mortar.

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[1] C. A. G. Weymouth, "Effects of Particle Interference in Mortars and Concretes," *Rock Products*, February 25, 1933, p. 26.

[2] C. C. Furnas, "Mathematical Relations for Beds of Broken Solids of Maximum Density," *Industrial and Engineering Chemistry*, Vol. 23, September, 1931, p. 1052.

[3] F. O. Anderegg, "The Application of Mathematical Formulas to Mortars," *Industrial and Engineering Chemistry*, Vol. 23, September, 1931, p. 1058.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 322 (1934).

In Table V are given additional test results furnished by laboratory No. 9. In the first half of the table are summarized results of tests made in accord-

TABLE III.—PERCENTAGE MEAN VARIATION IN COMPRESSIVE STRENGTH OF THREE TEST SPECIMENS FROM THEIR AVERAGE.

Each value is average percentage mean variation of three tests made on three days.

Laboratory	1 Day			3 Days			7 Days			28 Days		
	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix
CEMENT NO. 1												
No. 1	2.3	2.1	1.2	1.7	1.5	2.8	2.2	2.4	3.0	1.2	1.4	2.2
No. 2[a]	1.3	2.6	0.0	0.3	1.2	2.1	1.8	1.2	1.0	1.2	1.9	2.6
No. 3	1.7	1.7	2.0	1.8	2.9	1.6	2.1	1.9	3.4	2.0	3.2	3.3
No. 4	4.0	2.2	1.6	1.9	3.0	1.9	1.3	1.7	2.4	3.1	3.8	3.7
No. 5	2.1	2.8	1.6	2.0	1.7	1.6	0.6	1.8	3.2	2.1	2.1	1.2
No. 6	3.2	2.9	3.2	1.6	2.9	3.0	2.2	1.6	1.1	2.7	2.0	2.5
No. 7	3.5	3.6	3.5	2.3	2.5	2.5	1.4	3.4	3.2	1.4	3.6	2.0
No. 8	0.3	4.4	1.3	1.5	1.5	3.3	2.5	2.1	2.5	3.6	1.1	2.0
No. 9	2.5	2.3	2.5	2.0	3.0	1.1	2.4	3.8	2.1	2.4	1.4	1.7
No. 10	3.1	3.5	2.5	0.6	3.1	1.9	2.9	2.9	1.2	2.1	3.1	3.3
No. 11	2.1	3.8	0.9	2.3	2.0	1.4	1.1	0.8	1.9	2.7	2.1	1.5
No. 12	3.8	1.9	0.5	1.5	1.6	1.6	1.5	0.7	3.2	1.6	3.5	1.5
No. 13	5.2	4.9	3.3	2.4	1.7	3.2	3.9	2.4	4.9	3.7	4.5	5.6
No. 14	6.9	3.7	5.2	4.0	3.7	2.5	5.1	2.6	1.8	2.6	1.2	1.1
Average	3.0	3.0	2.1	1.8	2.3	2.2	2.2	2.1	2.5	2.3	2.5	2.4
CEMENT NO. 2												
No. 1	0.8	1.4	0.8	1.7	1.0	1.5	2.0	1.4	0.8	0.7	0.8	1.8
No. 2[a]	2.1	0.7	1.0	1.0	1.2	1.0	1.4	1.9	0.6	1.3	2.1	1.8
No. 3	1.2	1.8	1.0	1.8	0.8	1.4	1.4	1.2	2.0	1.5	0.9	2.4
No. 4	4.5	1.5	2.9	1.7	2.0	5.0	3.9	0.7	4.6	2.5	2.8	4.8
No. 5	2.8	0.9	1.2	0.7	1.7	1.9	0.9	1.4	3.2	2.0	0.9	2.6
No. 6	1.3	2.7	1.8	2.6	3.3	1.7	2.5	2.5	2.3	3.7	3.5	3.4
No. 7	2.6	1.7	3.1	2.9	3.5	1.7	2.1	2.9	1.4	2.0	2.8	1.8
No. 8	3.1	4.4	1.9	2.0	3.4	0.7	1.5	1.6	2.2	1.3	3.1	2.4
No. 9	1.4	2.5	1.6	0.9	0.4	2.4	1.9	1.6	1.1	0.9	1.3	2.1
No. 10	1.2	1.1	1.1	2.1	3.2	0.8	0.5	1.3	1.0	1.8	1.7	1.8
No. 11	0.8	1.4	1.7	1.8	1.0	0.9	1.1	1.3	0.9	1.0	2.3	0.7
No. 12	0.9	1.6	2.2	0.5	2.1	2.5	2.5	2.7	2.0	2.5	1.7	3.6
No. 13	2.3	1.2	2.9	1.4	2.2	2.9	6.9	4.3	1.5	5.8	4.2	2.1
No. 14	2.2	3.9	5.9	1.4	3.0	1.1	1.9	1.8	2.5	3.3	2.9	3.7
Average	1.9	1.9	2.1	1.6	2.1	1.8	2.2	1.9	1.9	2.2	2.2	2.5
CEMENT NO. 3												
No. 1	1.2	1.6	1.6	1.8	1.6	1.1	1.3	1.2	1.7	1.8	1.4	2.3
No. 2[a]	2.6	2.9	1.9	1.5	2.3	1.9	1.1	2.0	0.8	2.2	1.7	2.4
No. 3	2.8	1.9	1.7	2.0	2.4	1.5	1.1	1.1	0.9	1.9	1.2	1.9
No. 4	5.3	4.8	3.8	3.5	1.8	2.2	2.5	4.7	1.4	1.4	1.4	2.3
No. 5	2.8	1.4	1.4	1.4	1.1	1.5	2.1	2.4	1.0	1.6	2.5	2.1
No. 6	1.5	2.7	3.4	2.3	2.6	2.1	1.8	2.5	3.2	1.9	4.0	4.0
No. 7	4.0	3.3	3.7	4.0	3.7	3.1	3.8	4.8	2.0	4.1	4.2	3.1
No. 8	2.5	2.2	1.9	5.0	1.2	6.5	1.8	1.1	4.7	1.2	1.9	1.8
No. 9	2.0	2.1	1.1	2.0	2.1	1.5	2.5	2.4	2.4	2.0	1.2	1.5
No. 10	2.0	2.1	2.0	0.6	2.1	1.1	0.4	3.5	1.0	3.0	2.4	2.7
No. 11	1.5	2.8	2.4	1.6	2.1	0.5	1.5	1.4	1.3	1.8	0.9	2.0
No. 12	2.9	1.6	1.4	1.1	1.7	3.2	1.1	2.4	1.0	2.0	3.6	1.3
No. 13	4.2	5.1	3.5	4.4	3.3	3.1	2.6	3.0	2.7	5.4	4.0	4.7
No. 14	4.0	2.0	4.1	1.1	4.6	2.8	2.4	2.0	3.2	1.1	4.0	3.8
Average	2.8	2.6	2.4	2.3	2.3	2.3	1.9	2.5	1.9	2.2	2.5	2.6

[a] Added 110 g. banding sand to Bates mix.

ance with the outline of tests but considering the cement, water and potter's flint as the paste in the B mortar, and in the second half results of tests using Potomac River gravel No. 4 to $\frac{3}{8}$ in. instead of the low-absorptive pebbles in the B and P mortars. All of these results check very closely with those given in Table I (laboratory No. 9) except that the 28-day results are somewhat higher throughout for the Potomac River gravel, averaging 3.6 per cent higher.

TABLE IV.—SUMMARY OF PERCENTAGE MEAN VARIATIONS.

Cement	1 Day			3 Days			7 Days			28 Days		
	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix	Bates Mix	Pearson Mix	C 109 Mix
PERCENTAGE MEAN VARIATIONS OF COMPRESSIVE STRENGTH BETWEEN LABORATORIES (VALUES FROM TABLE I).												
No. 1	8.1	7.7	16.1	6.4	6.0	9.3	5.2	5.7	7.6	4.3	4.3	6.4
No. 2	7.2	5.9	6.4	5.6	4.8	4.6	5.1	4.2	6.1	4.8	4.0	6.3
No. 3	8.0	7.9	12.4	4.9	4.8	9.5	5.0	5.1	8.7	2.2	4.2	6.4
Average	7.8	7.2	11.6	5.6	5.2	7.8	5.1	5.0	7.5	3.8	4.2	6.4
AVERAGE PERCENTAGE MEAN VARIATIONS IN COMPRESSIVE STRENGTH OF THREE TESTS FROM THEIR AVERAGE (VALUES FROM TABLE II).												
No. 1	5.8	6.8	6.0	4.1	4.4	3.6	3.4	2.6	3.0	1.9	3.7	3.0
No. 2	2.9	2.4	3.3	2.8	3.1	2.1	3.2	2.5	2.2	2.1	2.0	2.0
No. 3	4.7	4.0	4.0	3.0	2.6	3.1	1.9	2.7	2.3	1.7	2.3	2.5
Average	4.5	4.4	4.4	3.3	3.4	2.9	2.8	2.6	2.5	1.9	2.7	2.5
AVERAGE PERCENTAGE MEAN VARIATIONS IN COMPRESSIVE STRENGTH OF THREE TEST SPECIMENS FROM THEIR AVERAGE (VALUES FROM TABLE III).												
No. 1	3.0	3.0	2.1	1.8	2.3	2.2	2.2	2.1	2.5	2.3	2.5	2.4
No. 2	1.9	1.9	2.1	1.6	2.1	1.8	2.2	1.9	1.9	2.2	2.2	2.5
No. 3	2.8	2.6	2.4	2.3	2.3	2.3	1.9	2.5	1.9	2.2	2.5	2.6
Average	2.6	2.5	2.2	1.9	2.2	2.1	2.1	2.2	2.1	2.2	2.4	2.5

The relations of the strength results of the pebble mortars to those of the C mortar and to the tension test results of the standard briquets (Figs. 1 and 2) are strikingly similar to Figs. 7 and 9 of the 1934 report. When the compressive strength results of the C mortar at 1, 3, 7, and 28 days are charted on the *y-axis* and the corresponding results for the B and P mortars on the *x-axis* (Fig. 1), the line joining the points curves very slightly toward the *y-axis* as does the line in the 1934 report (Fig. 7) showing the relation between graded Ottawa sand mortar and concrete strengths. When the concrete strength results of the 1934 report are plotted against the B and P mortar strengths the relation appears to be a straight line. When the tensile strength results of the present series are plotted on the *y-axis* and the compressive strength results of the B and P mortars on the *x-axis* (Fig. 2) the line joining the points curves sharply away from the *y-axis* as does the line in the 1934 report (Fig. 9) showing the relation between tensile strength of standard briquets and compressive strength of concrete. The inference drawn from these charts is that the relation of the strengths of the pebble

TABLE V.—ADDITIONAL TESTS MADE BY LABORATORY NO. 9.

BATES MIX

Cement, water and potter's flint considered as the paste. 25 g. cement, $13\frac{1}{2}$ ml. water, and 6 g. potter's flint (which is same relation between these three components as in the basic mix) added to the basic mix to obtain slumps within the specified range of $1\frac{5}{8}$ to $2\frac{3}{8}$ in. (1.62 to 2.37 in.).

Test	Changes in Basic Mix			Slump, in.	Flow			Compressive Strength of 2-in. Cubes, lb. per sq. in.			
	Cement, g.	Water, ml.	Potter's Flint, g.		10-in. Flow Table, per cent	Trough		1 day	3 days	7 days	28 days
						10 Drops, in.	20 Drops, in.				
Cement No. 1:											
No. 1	+25	+13.5	+6	2.37	113	1.2	2.5	670	2430	4280	7320
No. 2	+25	+13.5	+6	2.37	109	1.1	2.3	670	2430	4380	7360
No. 3	+25	+13.5	+6	2.12	107	1.3	2.5	650	2510	4340	7340
Average				2.29	110	1.2	2.4	663	2457	4333	7340
Cement No. 2:											
No. 1	+25	+13.5	+6	1.87	86	1.0	2.0	2620	4830	6060	7510
No. 2	+25	+13.5	+6	1.87	84	1.0	2.1	2640	4860	6100	7650
No. 3	+25	+13.5	+6	1.75	87	0.9	1.8	2580	4920	6060	7420
Average				1.83	86	1.0	2.0	2613	4870	6073	7527
Cement No. 3:											
No. 1	+25	+13.5	+6	2.37	108	1.3	2.6	1010	2270	3480	6290
No. 2	+25	+13.5	+6	2.37	108	1.0	2.2	1030	2190	3630	6400
No. 3	+25	+13.5	+6	2.37	109	1.3	2.6	1040	2310	3620	6480
Average				2.37	108	1.2	2.5	1027	2257	3577	6490

BATES MIX

Potomac River gravel ($\frac{3}{8}$ in. to No. 4) substituted for low absorptive gravel ($\frac{3}{8}$ in. to No. 4).

Cement No. 1:											
No. 1	+25	+13.5	0	2.37	100	1.0	2.3	610	2400	4330	7580
No. 2	+25	+13.5	0	2.25	109	1.3	2.6	650	2430	4270	7630
No. 3	+25	+13.5	0	2.12	105	1.4	2.7	640	2360	4500	7940
Average				2.25	105	1.2	2.5	633	2397	4367	7717
Cement No. 2:											
No. 1	+25	+13.5	0	1.62	80	0.8	1.8	2610	5020	6330	7930
No. 2	+25	+13.5	0	1.62	77	0.9	1.8	2680	5010	6530	7930
No. 3	+25	+13.5	0	1.62	85	0.8	1.6	2750	4840	6490	7560
Average				1.62	81	0.8	1.7	2680	4957	6450	7807
Cement No. 3:											
No. 1	+25	+13.5	0	2.37	111	1.3	2.6	980	2290	3460	6410
No. 2	+25	+13.5	0	2.25	109	1.3	2.6	1030	2160	3220	6860
No. 3	+25	+13.5	0	2.37	110	1.5	3.0	1030	2390	3580	6840
Average				2.33	110	1.4	2.7	1013	2280	3420	6703

PEARSON MIX

Potomac River gravel ($\frac{3}{8}$ in. to No. 4) substituted for low absorptive gravel ($\frac{3}{8}$ in. to No. 4).

Cement No. 1:											
No. 1	+25	+13.5	0	2.00	110	1.1	2.4	520	2120	3980	7310
No. 2	+25	+13.5	0	2.00	101	1.5	2.8	620	2220	4210	7090
No. 3	+25	+13.5	0	1.75	97	1.2	2.4	610	2280	4340	7580
Average				1.92	103	1.3	2.5	583	2207	4177	7327
Cement No. 2:											
No. 1	+25	+13.5	0	1.62	84	1.2	2.4	2620	4840	6300	7730
No. 2	+25	+13.5	0	1.62	81	1.1	2.3	2730	5030	6380	8090
No. 3	+25	+13.5	0	1.62	82	1.0	2.0	2720	5360	6740	8310
Average				1.62	82	1.1	2.2	2690	5077	6473	8043
Cement No. 3:											
No. 1	+25	+13.5	0	2.00	111	1.2	2.5	880	2150	3360	6360
No. 2	+25	+13.5	0	1.62	87	1.0	2.3	900	2060	3790	5950
No. 3	+25	+13.5	0	1.75	86	1.3	2.8	990	2210	3360	6390
Average				1.79	95	1.2	2.5	923	2140	3503	6233

mortars to those of standard briquets and of graded Ottawa sand mortar is the same as that of concrete. The compressive strength relation of the B and P mortars at 1, 3, 7, and 28 days is a straight line.

In regard to workability, water gain, and other characteristics of the mortars, nine laboratories gave opinions or comments while five offered no comment. The laboratories did not agree as to workability and water gain, some favoring one mortar and some another. It may be said in general that the pebble mortars were rated about the same as to workability and definitely better than the C mortar. The three mortars were rated about the same as to water gain at the surface of the cubes. However, one laboratory siphoned water from the tops of the cubes and found that the pebble mortars retained the water much better than the C mortar. Another laboratory came to the same conclusion by observing water enter a depression in the mortar made with the trowel handle. Several found that the pebble mortars required too much energy to mix by hand and suggested that mechanical mixers would be necessary for routine testing. Others pointed out that extra care had to be taken in molding and finishing the cubes because of the larger pebbles. Two laboratories (Nos. 4 and 9) reported that they are experimenting with high-frequency vibration for placing the mortar in the molds and that the method appears to have merit.

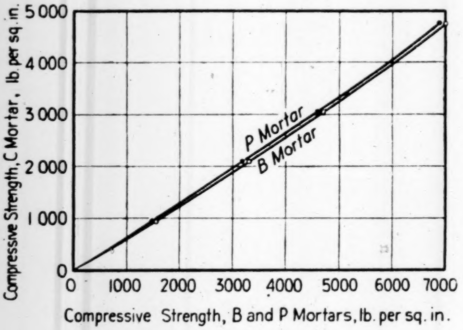

FIG. 1.—Relation Compressive Strength of C Mortar to Compressive Strength of B and P Mortars.

Average strength results of 3 cements by 14 laboratories plotted for each period. (1, 3, 7 and 28 days.)

The entrained air in the mortars was determined by one laboratory using the Pearson and Collins method.[1] The results range from about 1.0 to 1.5 per cent for the pebble mortars and from about 5.0 to 8.0 per cent for the C mortar. Another laboratory computed air voids from the weights of unit volumes of the mortars and obtained about 0.5 per cent for the pebble and about 9.5 per cent for the C mortar.

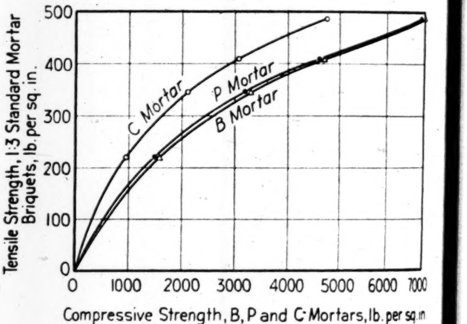

FIG. 2.—Relation Between Tensile Strength (1:3 Briquets) and Compressive Strength of B, P and C Mortars.

Average strength results of 3 cements by 14 laboratories plotted for each period. (1, 3, 7, and 28 days.)

The slump and flow results are not given here due to their voluminous nature. Considering the C mortar (the consistency of which was not controlled) and the results of the six laboratories making complete tests, the flow table and the Burmister flow trough gave good concordance in each laboratory and the slump cone fair concordance, but the results of the three methods between laboratories varied quite widely. The Burmister flow results are the least variable between laboratories, and those of the flow table between tests of the same laboratory. The average percentage mean variations between tests, or rounds, in each laboratory for the three cements are of the order of 3.0 for the flow table, 7.0 for the Burmister flow trough (20 drops), and 13.0 for the slump cone; and between laboratories 16.0 for the Burmister (20 drops), 22.0 for the flow table, and 27.0 for the slump cone. Ten drops of the Burmister flow trough gave results which were not quite as satisfactory as 20 drops. The percentage mean variations computed from results of laboratories Nos. 1, 4, 6, 7, 9, and 10 are as follows:

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[1] J. C. Pearson and H. G. Collins, "A Method for Determining the Air Content of Freshly Mixed Mortars and Concretes," *Journal* and *Proceedings*, Am. Concrete Inst., Vol. 32, January-February, 1936, p. 298.

	Burmister Flow Trough		10-in. Flow Table	Small Slump Cone
	10 Drops	20 Drops		
Between Laboratories:				
C Mortar (average 3 cements)	17.0	16.0	22.0	27.0
B Mortar (average 3 cements)	13.0	13.0	22.0	[a]
P Mortar (average 3 cements)	16.0	12.0	34.0[b]	[a]
Between Tests in Same Laboratory:				
C Mortar (average 3 cements)	12.0	6.6	3.2	13.2
C Mortar (cement No. 1 only)	....	5.9	3.1	[a]
B Mortar (cement No. 1 only)	....	10.3	4.2	[a]
P Mortar (cement No. 1 only)	....	9.1	5.1	[a]

[a] Slump controlled.

[b] If unusually high figure (61 per cent) for cement No. 3 is eliminated this figure becomes 20.0 per cent.

CONCLUSIONS

1. The B mortar gave strengths slightly higher (about 3 per cent) than the P mortar and decidedly higher (about 53 per cent) than the C mortar.

2. The relation between the strengths of the B and P mortars at 1, 3, 7, and 28 days is a straight line.

3. The compressive strength of the B or the P mortar *versus* that of the C mortar (Fig. 1) is strikingly similar to the compressive strength of the concrete *versus* that of the graded Ottawa sand mortar in the 1934 series (Fig. 7).[1]

4. The compressive strength of the B or the P mortar *versus* the tensile strength of the standard briquets (Fig. 2) is similar to the compressive strength of the concrete *versus* the tensile strength of the standard briquets in the 1934 series (Fig. 9).[1]

5. A constant ratio appears to exist between the compressive strength of the B or the P mortar and the compressive strength of the concrete of the 1934 series[1] at any test period up to and including 28 days.

6. The compressive strength figures of the C mortar are much nearer to those of concrete as now used in practice for a cement-water ratio of 1.88 than are those of the B or the P mortar.

7. The uniformity of strength results of the pebble mortars is about the same, the B mortar rating a shade better, and both definitely better than the C mortar. The grand average percentage mean variations are as follows:

	B MORTAR	P MORTAR	C MORTAR
Between laboratories....	5.4	5.6	8.3
Between rounds in same laboratory......	3.1	3.3	3.1
Between cubes at same periods......	2.2	2.3	2.2
Average.....	3.6	3.7	4.5

8. Taking the majority of the opinions of the laboratories which expressed

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 334 (1934).

opinions as a basis, the B and P mortars rate about equal and both superior to the C mortar in regard to workability.

9. The B and C mortars rate about the same and somewhat better than the P mortar in regard to water gain on the tops of the cubes after molding. However, the pebble mortars retain water much better than the C mortar, as pointed out by two laboratories.

10. The pebble mortars were more tiresome to mix and required more care to mold properly than did the C mortar.

11. The substitution of Potomac River gravel (No. 4 to $\frac{3}{8}$-in.) for the low-absorptive gravel by one laboratory did not affect the results appreciably except to increase the 28-day strength about 3.6 per cent.

12. The Burmister flow trough results are the best of the three methods in tests between laboratories, and the flow table results best between tests of the same laboratory. Twenty drops of the Burmister flow trough gave more uniform results than ten drops with these mortars.

Respectfully submitted on behalf of the Working Committee,

O. L. MOORE,
Chairman.

DISCUSSION

MR. H. J. GILKEY[1] (*by letter*).—Rarely does one see a more satisfying or well presented lot of data than that of the Report on Pebble Concrete. Moreover, the nearness with which the Bates and Pearson mixtures came to giving the same answer and the excellent correlation between the tests from these mixtures and those from the C 109 mixture is encouraging. Since the C 109 mixture was almost identical with that used for the tests reported in 1934,[2] conclusion No. 5 seems to be justified. Judging from the results of comparative tests of many concrete and mortar mixtures for quite a range of curings, ages, and test conditions, there seems to be little reason to doubt that a correlation which holds for ages up to 28 days will probably hold for later ages and for almost any mutually common curing or test condition. In spite of the several apparent advantages of the pebble mortars, the committee has obviously recognized that there are other aspects on which study is desirable and that it would be unwise at this time to switch from the current C 109 mixture. The demonstrated efficiency of the C 109 mixture as a correlating medium between cement and concrete performance removes the need for haste in selecting the mixture finally believed to supply the best solution to the problem. Standards and methods of test (tentative or otherwise) should not be changed lightly just to take advantage of intermediate or inconsequential winnings.

The fact that the Bates and Pearson mixtures with cement aggregate ratios of approximately 1:5 and 1:5.6 gave strengths more than 50 per cent above those of much richer 1:2.77, C 109 mixture (all at the same water-cement ratio), is too illuminating and significant to permit to pass unnoticed even though this is probably not an appropriate phase of the report for discussion here. For that reason a discussion enlarging upon that aspect of the report was prepared and published in the October issue of the *ASTM Bulletin* to which interested readers are referred. Other data of a similar nature are cited in a discussion of the paper by C. A. G. Weymouth entitled "A Study of Fine Aggregate in Freshly Mixed Mortars and Concretes."[3]

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[1] Professor and Head, Department of Theoretical and Applied Mechanics, Iowa State College, Ames, Iowa.

[2] O. L. Moore, Report of Working Committee on Plastic Mortar Tests for Portland Cement, *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 322 (1934.)

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 354 (1938).

REPORT ON COOPERATIVE AUTOCLAVE TESTS OF PORTLAND CEMENT

Sponsored by Working Committee on Volume Change and Soundness

In the 1936 and 1937 reports of Committee C-1,[1] a program of current investigations by the Working Committee on Volume Change and Soundness of Portland Cement was described and methods of test and test data were presented. The recent activities of the Working Committee have been concerned chiefly with the carrying out of these programs and with the interpretation of the results. The principal aim of the work of the past year has been to develop, through a cooperative series of tests, a procedure for carrying out the autoclave test which would give a quick quantitative measure of soundness and enable comparable results to be obtained in tests by different laboratories. This report covers results of this cooperative series which was conducted on 35 cements in 13 laboratories.

The principal factors under investigation in these tests were:

1. Uniformity in results obtainable in repeat tests on the same cement by a given laboratory and by different laboratories (Group 1 of Outline in Appendix A).
2. Duration of time that specimens are held at maximum temperature of 420 F. (Group 2).
3. Variation in the quantity of mixing water (Group 3).
4. Variation in procedure as to treatment of test bars before placing in and upon removal from autoclave (Group 4).
5. Use of bars having an effective gage length of 5 in. as compared with bars of 10-in. effective gage length (Group 5).
6. Soundness tests by present standard A.S.T.M. method (Group 6).

Cements.—The commercial cements used in these tests were obtained through the Portland Cement Association and were carefully sampled and distributed in sealed metal containers. Of the 35 cements tested, 21 were normal portland cements, 6 high-early strength, 3 moderate-heat, 2 sulfate-resisting, and 3 portland pozzolan cements.

All laboratories tested each of the 35 cements for soundness by the standard A.S.T.M. method (group 6) and by the autoclave, following the procedure suggested as a result of the earlier work, the bars being exposed in the autoclave for a total of 5 hr. In addition to this normal 5-hr. period in the autoclave, some of the laboratories tested certain of the cements using 3- and 20-hr. periods, and also a modified procedure for handling the specimens before and after autoclaving.

The suggested procedure requires the use of neat cement paste of normal consistency. In order to investigate the effect of quantity of mixing water, some laboratories made bars for several of the cements using $27\frac{1}{2}$ and 40 per cent water by weight.

Eleven laboratories used bars having an effective gage length of 10 in., while two used bars of 5-in. gage length. In one group of tests, (group 5) several of the laboratories made additional tests on bars of 5-in. gage length.

The suggested procedure as well as the modifications of it that were used in these tests are described in Appendices A and B to this report.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 225 (1936); Vol. 37, Part I, pp. 276 and 290 (1937).

Cooperating Laboratories.—The 13 laboratories which cooperated in making the tests in whole or part are listed below in alphabetical order but not in the order in which they appear in the accompanying tables:

LABORATORY	INDIVIDUAL
California Portland Cement Co., Colton, Calif.	W. C. Hanna
Kansas State Agricultural College, Manhattan, Kans.	C. H. Scholer
Lehigh Portland Cement Co., Allentown, Pa.	R. N. Young
Lone Star Cement Corp., Hudson, N. Y.	M. A. Swayze
Missouri Portland Cement Co., St. Louis, Mo.	J. J. Fox
New York State Highway Dept., Albany, N. Y.	Ira Paul
Pennsylvania State Highway Dept., Harrisburg, Pa.	H. S. Mattimore
Pennsylvania-Dixie Cement Corp., Nazareth, Pa.	W. H. Klein
Portland Cement Association, Chicago, Ill.	H. F. Gonnerman
Thompson & Lichtner Co., Boston, Mass.	Miles N. Clair
Universal Atlas Cement Co., Chicago, Ill.	O. L. Moore
U. S. Bureau of Public Roads, Washington, D. C.	F. H. Jackson
U. S. Bureau of Standards, Washington, D. C.	P. H. Bates

DATA OF TESTS

Chemical Analyses and Miscellaneous Tests.—All of the cements were analyzed for chemical constituents and the results are shown in Table I. Included in this table are the results of floc tests made in accordance with the procedure of Ira Paul of the New York Department of Public Works, and clear-point sugar test values supplied by Thaddeus Merriman of the New York Board of Water Supply.

Normal consistency and soundness, as determined by each laboratory in accordance with standard A.S.T.M. methods, are reported in Table II, together with surface areas, as determined by laboratory 4 using the Wagner turbidimeter, and times of setting by laboratory 9 using the Gillmore needles.

Autoclave Test Data.—The results of the autoclave tests reported by the cooperating laboratories are summarized in Tables III to VI. Table III gives the results of tests made on each cement on three different days in accordance with the normal 5-hr. exposure (3 hr. at maximum temperature of 420 F.). In Table IV are tabulated the results of autoclave tests made under the several different conditions of tests studied. In two or three laboratories the bars subjected to the normal 5-hr. period in the autoclave (3 hr. at 420 F.) were tested for a second and third time by the same cycle. Results of these repeat tests are given in Table V. A summary of the results for all conditions of test and for all laboratories is given in Table VI.

Effect of Duration of Exposure on Autoclave Expansion.—Expansions for the 5-hr. exposure (3 hr. at 420 F.) from Table III are compared in Figs. 1(*a*) and (*b*) with those from Table IV for 3 hr. (1 hr. at 420 F.) and 20 hr. (18 hr. at 420 F.) exposures. In Fig. 1(*a*) the cements are arranged in order of their expansions during the 5-hr. exposure. It will be observed that the expansion increased with the duration of exposure, but for most of the cements the expansions were relatively low for all periods of exposure.

Effect of Quantity of Mixing Water.—The influence on expansion of increasing the amount of mixing water from that required for A.S.T.M. normal consistency (average, 25 per cent by weight for the 35 cements) to 27½ and 40 per cent by weight of cement is shown graphically in Figs. 2(*a*) and (*b*), and in Figs. 3(*a*) and (*b*). In all cases the effect of increasing the water content of the paste was to increase the expansion. Cements which in the normal 5-hr. exposure showed more than about 0.5 per cent expansion, seemed to show the greatest increase in expansion when 40 per cent mixing water was used. It is interesting to note also that the expansions of bars containing 40 per cent mixing water during 5 hr. in the autoclave were abou of the same order of magnitude as th expansion of bars of normal consistenc during 20 hr. in the autoclave (Fig. 3(g)

Results for Modified Test Procedure.—Comparison of the expansions obtaine for the normal and modified procedure

TABLE I.—CHEMICAL ANALYSES OF CEMENTS.

Of the 35 commercial cements represented, 33 were furnished by the manufacturers and 2 were purchased on the open market. bags of each brand were thoroughly mixed, carefully sampled, and shipped to the cooperating laboratories in double friction top metal containers with instructions not to open until time of test. Included in the 35 cements were: 21 normal portland cements, 6 early strength, 3 moderate-heat, 2 sulfate-resisting, and 3 portland pozzolan cements.

Chemical analyses made by the Portland Cement Association Research Laboratory in accordance with their usual methods. value is the average of 2 or more determinations. Cements 33, 34, and 35 contained admixtures insoluble in HCl or HNO_3 necessitat analysis for SiO_2, Fe_2O_3, Al_2O_3, CaO and MgO by methods for insoluble silicates. Other constituents of these three cements determi by usual methods for portland cement and values represent acid soluble material only, except for TiO_2 which represents total TiO_2 prese

Values of SiO_2, Fe_2O_3, Al_2O_3, CaO, and MgO include insoluble residue, FeO, $TiO_2 + P_2O_5$, free CaO, and Mn_2O_3, respectively. Ferr oxide includes any metallic iron that may be present.

Free CaO content of cements determined by modified Bogue-Lerch method; values include any $Ca(OH)_2$ that may have been form In calculating compound composition, allowance was made for free CaO.

Floc determined in accordance with procedure of Ira Paul outlined on page 140 of the *Proceedings* of the Twelfth Annual Conventi of the Association of Highway Officials of the North Atlantic States, 1936.

Clear-point sugar values, supplied by Thaddeus Merriman, represent total milliliter of 0.5 *N* HCl required to clarify as well as neutralize 25 ml. of filtrate obtained according to method for sugar test given in Board of Water Supply, City of New York Specificati for Portland Cement C-333, Item 21, Section 21.10.

Cement	Oxide Analysis, per cent															Calculated Compound Composition, per cent						Floc, per cent by Wt. 7d[a]
	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Ign. Loss	Ins. Res.	FeO	TiO_2	P_2O_5	Free CaO	Mn_2O_3	C_3S	C_2S	C_3A	C_4AF	$CaSO_4$	Free CaO	
No. 1..	20.55	3.08	6.40	63.88	2.77	1.77	0.16	0.17	1.21	0.23	0.28	0.34	0.09	1.33	0.71	46.0	24.3	11.8	9.4	3.0	1.33	3.79
No. 2..	21.12	3.15	6.56	63.24	2.22	1.84	0.37	0.63	0.86	0.21	0.15	0.31	0.22	1.40	0.26	37.4	32.4	12.1	9.6	3.1	1.40	7.86
No. 3..	21.44	2.60	5.21	63.12	4.16	1.60	0.24	0.85	0.88	0.15	0.10	0.23	0.06	1.12	0.07	46.1	26.7	9.4	7.9	2.7	1.12	2.83
No. 4..	20.94	2.65	5.46	62.70	3.55	1.58	0.15	0.57	2.28	0.30	0.09	0.28	0.93	3.01	0.07	38.8	30.8	10.0	8.1	2.7	3.01	4.34
No. 5..	20.22	3.53	5.84	60.82	4.65	1.51	0.50	1.02	1.89	0.14	0.23	0.27	0.10	0.57	0.05	43.0	25.6	9.5	10.7	2.6	0.57	0.60
No. 6..	20.67	2.41	4.26	63.73	4.12	1.88	0.22	0.65	2.27	0.38	Tr.	0.24	0.10	1.50	0.07	58.8	14.9	7.2	7.3	3.2	1.50	2.38
No. 7..	22.35	3.34	4.22	64.25	2.40	1.54	0.21	0.45	1.28	0.17	Tr.	0.23	0.12	0.92	0.12	50.4	26.1	5.5	10.2	2.6	0.92	0.18*
No. 8..	19.44	2.47	6.80	64.27	2.66	1.80	0.28	0.92	1.14	0.10	0.04	0.27	0.32	1.89	0.09	51.8	16.7	13.8	7.5	3.1	1.89	10.22
No. 9..	21.40	2.87	4.90	62.60	4.03	1.77	0.13	0.35	1.89	0.10	Tr.	0.29	0.33	1.01	0.07	46.0	26.7	8.1	8.7	3.0	1.01	1.79
No. 10..	20.52	3.34	5.94	63.02	3.20	1.79	0.27	0.70	1.25	0.17	0.05	0.30	0.08	1.07	0.04	46.4	23.8	10.1	10.2	3.0	1.07	2.72
No. 11..	21.58	4.75	4.20	65.55	0.70	1.64	0.48	0.24	0.96	0.18	Tr.	0.32	0.24	0.84	0.06	59.7	16.8	3.1	14.5	2.8	0.84	0.27*
No. 12..	20.17	3.13	6.61	62.35	3.06	1.85	0.35	0.77	1.59	0.19	0.04	0.28	0.32	1.05	0.08	42.1	26.1	12.2	9.5	3.1	1.05	7.11
No. 13..	21.50	2.60	5.22	62.45	4.37	2.03	0.26	0.73	1.08	0.15	Tr.	0.27	0.09	0.37	0.08	44.7	27.9	9.4	7.9	3.5	0.37	0.63
No. 14..	21.38	2.19	5.62	62.89	4.02	1.77	0.22	0.43	1.53	0.10	0.06	0.22	0.19	0.46	0.06	45.7	26.9	11.2	6.7	3.0	0.46	0.69
No. 15..	21.21	2.03	5.85	64.87	2.41	1.65	0.18	0.52	1.37	0.15	Tr.	0.27	0.05	1.37	0.04	50.4	22.8	12.1	6.2	2.8	1.37	5.60
No. 16..	21.72	2.45	5.74	65.76	1.18	1.56	0.04	0.15	1.40	0.18	0.05	0.33	0.11	1.55	0.08	49.8	24.7	11.1	7.5	2.7	1.55	1.44
No. 17..	20.97	2.21	5.59	63.29	4.41	1.75	0.14	0.57	1.28	0.12	Tr.	0.29	0.07	0.85	0.05	49.1	23.1	11.1	6.7	3.0	0.85	3.89
No. 18..	21.07	2.70	7.13	61.43	2.92	1.69	0.08	0.82	2.43	0.28	0.45	0.37	0.04	1.10	0.04	28.8	38.7	14.3	8.2	2.9	1.10	11.42
No. 19..	21.14	2.49	6.72	62.81	1.72	1.81	0.95	0.51	2.11	0.18	0.19	0.39	0.10	2.05	0.06	32.8	35.9	13.6	7.6	3.1	2.05	3.97
No. 20..	21.75	2.45	5.17	64.61	2.31	1.67	0.31	0.65	1.22	0.19	Tr.	0.27	0.06	1.89	0.15	47.0	26.9	9.6	7.5	2.8	1.89	8.75
No. 21..	20.82	3.74	6.09	63.59	1.40	1.68	0.07	0.66	1.98	0.36	0.05	0.34	0.16	1.33	0.14	44.1	26.4	9.8	11.4	2.9	1.33	1.38
No. 22..	19.81	2.83	5.45	64.28	2.98	2.26	0.09	0.73	1.55	0.14	0.23	0.30	0.09	1.03	0.06	59.8	11.7	9.7	8.6	3.8	1.03	6.50
No. 23..	18.83	2.63	5.21	64.45	3.31	1.75	0.16	0.58	3.12	0.14	0.29	0.30	0.54	5.33	0.07	53.8	13.4	9.4	8.0	3.0	5.33	11.04
No. 24..	19.31	3.06	6.52	63.74	3.33	2.38	0.29	0.50	0.98	0.12	0.04	0.28	0.28	0.60	0.09	55.3	13.6	12.1	9.3	4.0	0.60	12.09
No. 25..	20.25	2.04	5.07	63.34	4.25	2.45	0.19	0.28	2.20	0.17	0.06	0.21	0.15	1.87	0.06	52.3	18.6	10.0	6.2	4.2	1.87	6.52
No. 26..	19.63	3.43	5.91	63.46	2.93	2.35	0.26	0.64	1.49	0.19	0.05	0.30	0.08	1.50	0.04	51.7	17.3	9.9	10.4	4.0	1.50	4.64
No. 27..	19.60	2.16	5.58	65.49	2.35	2.37	0.21	0.78	1.54	0.11	0.05	0.24	0.25	2.78	0.07	58.9	11.7	11.1	6.6	4.0	2.78	11.20
No. 28..	19.93	4.87	5.66	60.97	2.72	1.84	0.10	1.51	2.58	0.28	0.09	0.27	0.09	1.29	0.07	41.2	26.1	6.8	14.8	3.1	1.29	0.25*
No. 29..	21.52	4.77	5.22	61.66	2.62	1.72	0.17	0.60	1.89	0.13	0.04	0.29	0.11	0.81	0.18	37.3	33.6	5.8	14.5	2.9	0.81	0.26*
No. 30..	23.96	2.08	3.98	64.90	1.89	1.70	0.23	0.55	1.14	0.08	Tr.	0.23	0.05	1.54	0.12	41.2	37.6	7.0	6.3	2.9	1.54	5.00
No. 31..	23.26	4.16	3.52	63.66	1.49	1.75	0.35	0.43	1.51	0.18	0.04	0.13	0.06	1.57	0.05	41.3	35.5	2.3	12.7	3.0	1.57	0.36*
No. 32..	26.11	1.25	1.89	64.22	2.49	1.96	0.10	0.15	1.90	0.11	Tr.	0.12	Tr.	1.81	0.10	35.5	48.1	2.9	3.8	3.3	1.81	0.88
No. 33..	31.59	2.26	6.65	53.35	1.87	1.51	0.37	0.15	1.87	14.52	0.06	0.33	0.16	1.49	Tr.	....	....	....	....	....	....	3.55
No. 34..	31.73	3.69	6.34	48.06	3.58	1.90	0.44	0.37	2.92	16.48	0.21	0.34	0.14	0.90	0.09	....	....	....	....	....	....	0.30*
No. 35..	26.19	4.64	8.13	54.10	1.34	1.88	0.08	0.73	2.51	11.38	0.19	0.45	0.15	1.48	0.15	....	....	....	....	....	....	1.29

[a] Each value is the average of two determinations except those followed by an asterisk which represent single determinations.

TABLE II.—MISCELLANEOUS TESTS OF CEMENT.

NOTE.—All pats were reported to be sound in A.S.T.M. Standard Steaming Test, except as noted.

Laboratory	Cement Number																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WATER FOR NORMAL CONSISTENCY, PER CENT																																			
No. 1	23.8	23.0	23.0	25.4	22.6	26.0[a]	23.4	25.4	26.6	24.0	24.4	23.0	24.6	23.0	23.5	23.2	23.6	24.0	24.4	24.4	24.4	26.4[a]	28.0[a]	24.4	25.8[a]	28.0	26.0	24.0	24.0	25.2	25.2	24.0	31.0[a]	32.0[a]	27.8
No. 2	24.5	23.0	23.0	27.5	22.0	25.5	23.2	24.5	26.8	25.0	24.0	23.0	25.0	23.0	24.0	24.5	23.5	23.5	24.5	24.0	24.0	27.0	27.5	24.5	26.0	28.5	26.2	24.0	24.5	27.0	26.0	25.0	30.0	31.5	28.5
No. 3	24.0	23.5	23.6	25.5	22.4	25.5	24.0	25.0	25.6	24.1	23.6	23.5	24.0	23.6	24.0	23.4	23.8	24.4	24.0	24.0	23.6	24.4	27.6	24.0	25.2	27.4	25.6	24.0	24.0	25.2	24.8	23.4	31.0	30.0	27.4
No. 4	23.5	23.5	23.5	24.5	22.5	25.5	24.5	25.5	25.0	25.0	23.5	24.0	23.5	23.5	24.5	23.5	24.0	25.0	25.0	24.5	23.0	25.0	27.0	23.5	23.5	27.0	25.5	24.0	24.0	25.0	25.0	23.5	30.0	31.0	25.5
No. 5	23.0	23.7	24.0	24.5	22.5	25.0	24.0	26.0	25.5	24.5	23.0	23.0	22.5	22.5	24.5	23.0	24.5	24.5	24.0	24.5	22.5	24.0	26.5	24.0	23.5	27.5	25.5	24.0	23.5	24.5	24.5	24.0	28.5	29.0	27.5
No. 6	25.0	24.0	23.0	26.0	22.0	25.0	24.0	25.5	26.0	24.0	24.0	24.0	24.0	23.5	25.0	24.0	23.5	24.0	25.0	24.5	24.0	25.5	28.5	24.0	27.0	27.0	26.0	24.0	23.5	25.0	24.0	25.0	32.0[b]	32.0[b]	27.0
No. 7	23.0	25.0	26.0	27.0	23.0	26.0	24.0	25.0	26.0	25.0	24.0	24.0	24.0	23.0	24.0	24.0	25.0	25.0	23.0	24.0	23.0	25.0	26.5	23.0	23.0	27.0	25.5	24.5	24.0	25.0	24.0	23.0	30.0	30.0	27.0
No. 8	25.0	24.0	23.5	26.0	23.5	26.0	24.5	25.5	25.5	24.5	24.5	23.0	24.5	24.5	25.0	24.0	24.5	24.5	24.5	24.5	23.5	25.5	28.0	26.0	26.0	27.5	26.5	25.0	25.0	28.0	25.5	25.0	31.0	32.0	29.0
No. 9	23.0	23.0	23.0	25.0	22.0	25.2	24.0	24.3	25.4	24.0	23.5	22.8	24.0	23.0	23.8	22.8	24.0	24.0	23.5	24.0	23.5	25.0	27.0	24.0	24.6	27.4	26.1	24.0	24.0	24.8	24.6	23.5	37.0	32.5	28.0
No. 10	24.0	24.0	24.0	25.0	21.0	25.0	24.0	25.0	26.0	23.0	24.0	23.0	24.0	23.0	24.0	24.0	23.0	23.5	25.0	25.0	24.0	26.0	28.0	23.5	27.0	28.0	26.0	24.0	24.0	25.0	25.0	25.0	31.0[b]	31.0	28.0
No. 11	23.5	24.0	23.5	25.0	24.0	26.0	24.0	24.5	25.0	25.0	24.0	23.5	24.0	24.0	24.0	23.0	24.0	24.0	24.0	24.5	24.5	26.0	27.0	24.5	25.5	27.5	25.5	24.0	24.5	24.5	24.5	24.0	31.0	31.0	27.0
No. 12	25.0	23.3	23.0	26.5	22.0	24.8	24.0	24.7	25.6	23.9	23.6	23.4	23.9	23.1	24.2	23.2	23.7	24.0	24.1	23.7	24.3	26.7	27.0	25.0	25.8	27.3	25.3	23.4	23.6	25.4	24.5	24.1	30.1	31.9	27.5
No. 13	25.0	23.5	23.0	26.0	22.0	25.0	24.5	25.0	25.0	24.0	23.0	23.0	24.0	23.0	24.0	24.0	24.0	25.0	24.0	23.5	24.0	26.0	30.0	24.5	25.0	27.5	26.0	23.0	24.0	25.0	25.0	25.0	32.0	32.0	27.0
Mean	24.0	23.7	23.6	25.7	22.4	25.4	24.0	25.1	25.7	24.3	23.8	23.3	24.0	23.2	24.2	23.6	23.9	24.2	24.2	24.2	23.7	25.6	27.6	24.2	25.2	27.5	25.8	24.1	24.0	25.3	24.8	24.2	31.1	31.3	27.5
PERCENTAGE PASSING NO. 325 SIEVE, AND SPECIFIC SURFACE, SQ. CM. PER GM., BY WAGNER TURBIDIMETER																																			
No. 4	85.5 1780	85.9 1760	82.5 1585	92.8 1958	80.4 1538	91.4 1680	84.4 1430	82.0 1510	95.8 2148	91.1 1753	91.6 1813	85.8 1723	85.1 1680	83.3 1725	85.5 1670	81.3 1705	85.8 1485	83.0 1673	84.4 1898	91.6 1753	85.5 1823	98.6 2520	98.2 2580	95.4 2175	95.6 2935	99.6 2740	94.6 2130	87.6 1845	87.4 1763	95.6 1978	85.0 1615	94.8 2130	95.0 2353	91.2 2250	87.3 1985
INITIAL AND FINAL TIMES OF SETTING BY GILLMORE NEEDLES (HOURS: MIN.)																																			
No. 9	3:05 5:56	2:31 4:32	2:43 4:24	3:22 5:46	3:07 5:31	3:17 6:09	3:10 6:02	2:35 4:33	3:05 5:10	2:56 5:01	3:43 5:45	2:47 5:10	3:15 6:50	3:08 6:06	2:28 5:03	2:38 4:36	2:46 5:41	2:32 5:29	1:35 4:09	2:24 5:16	3:00 4:55	2:39 4:34	1:10 4:20	2:13 4:08	1:37 3:00	2:15 4:04	2:52 5:12	2:25 5:49	2:33 5:53	2:49 5:24	3:00 7:17	2:32 5:25	1:39 7:55	4:14 9:31	4:40 7:53

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[a] Fine radial cracks indicated by rise of water when bottom of pat was wetted.

[b] Failed.

TABLE III.—EXPANSIONS FOR AUTOCLAVE TESTS MADE ON 3 DIFFERENT DAYS.

Specimens 1 by 1 in. in cross-section. Length as noted.
Specimens in autoclave for 5 hr. (3 hr. at maximum temperature of 420 F.).
Specimens made in accordance with procedure given in outline in Appendix B to this report.
Results in brackets [ ] are for only one bar per batch and are omitted from the summations.

Unless otherwise noted, each value of expansion (minus sign indicates contraction) is the average of tests on 2 bars made from single batches on each of three different days. Values are expressed as percentage change in length of bar during autoclaving.
Maximum deviations of individual bars (Max. Dev.) are the greatest differences in percentage expansion for any one bar from the mean of the 6 bars for a given laboratory.

Standard deviation = $\sqrt{\frac{\Sigma d^2}{n}}$; where d is the deviation from the mean, and n is the number of observations.

Laboratory	Gage Length, in.		Expansion, per cent For Cement Indicated																	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
No. 1[a]	10[d]	Mean	.076	.142	.533	.216	.868	.167	.031	.580	.133	.089	−.004	.160	.201	.111	.169	−.008	.961	.481
		Max. Dev.	+.003	+.009	+.207	−.014	+.112	−.022	±.009	+.079	±.006	−.010	−.008	−.016	−.014	−.007	−.027	+.001	+.121	+.019
No. 2[b]	10	Mean	[.079	.138	.472	.221	.805	.148	.030	.516	.141	.104	−.010	.143	.189	.111	.153	−.006	.731	.468]
		Max. Dev.	±.004	+.005	+.022	±.003	−.051	−.009	±.001	+.069	±.003	+.006	−.006	±.005	±.009	±.001	±.011	−.003	−.025	±.007
No. 3[b]	10	Mean	.077	.133	.522	.229	.864	.151	.027	.513	.145	.087	−.014	.145	.175	.109	.148	−.008	.836	.531
		Max. Dev.	−.006	±.004	±.011	+.004	+.031	−.013	−.004	+.009	+.004	+.004	−.006	±.008	+.014	+.011	+.025	−.009	−.034	+.035
No. 4[b]	10	Mean	.09	.15	.54	.23	.88	.14	.03	.56	.15	.10	−.015	.15	.14	.12	.15	−.01	.928	.40
		Max. Dev.	±.010	+.008	±.030	±.005	+.047	±.010	.00	+.022	±.005	+.010	±.005	+.017	−.022	−.007	+.007	.00	+.100	+.090
No. 5[b]	10	Mean	.07	.12	.48	.23	.86	.14	.03	.56	.14	.08	−.02	.14	.15	.10	.14	−.01	.81	.50
		Max. Dev.	−.010	+.018	−.055	−.007	−.018	−.022	−.007	−.007	+.007	+.007	.00	+.007	+.011	±.005	−.025	−.008	+.222	−.065
No. 6[b]	10	Mean	.084	.137	.464	.232	.824	.132	.025	.497	.148	.080	−.018	.140	.145	.112	.135	−.014	.767	.503
		Max. Dev.	±.003	−.007	+.072	−.004	+.018	±.007	±.003	−.026	+.004	±.005	+.004	+.009	−.008	±.003	+.009	+.002	−.042	−.015
No. 7[b]	10	Mean	.086	.161	.613	.242	1.028	.167	.039	.498	.150	.105	−.010	.160	.197	.121	.185	−.008	1.042	.608
		Max. Dev.	−.006	−.011	−.130	+.007	−.102	−.024	+.005	+.028	−.007	−.011	+.007	+.013	+.030	−.010	±.024	±.008	+.126	−.057
No. 8[b]	10	Mean	.08	.15	.52	.23	.88	.15	.03	.48	.13	.09	−.01	.14	.19	.11	.18	−.01	1.11	.52
		Max. Dev.	+.007	+.007	−.043	−.007	−.137	+.028	−.008	−.065	−.016	+.028	±.010	±.015	±.005	+.007	−.013	+.007	+.348	±.020
No. 9[b]	5	Mean	.096	.179	.612	.253	1.005	.197	.052	.633	.162	.125	.003	.171	.220	.131	.206	−.002	1.102	.614
		Max. Dev.	±.004	−.019	−.068	+.009	+.039	+.033	+.004	+.057	±.002	±.005	−.004	±.009	−.020	±.007	+.012	+.002	+.094	−.034
No. 10[a]	10	Mean	[.073	.130	.429	.177	.329	.108	.021	.486	.107	.062	−.009	.112	.113	.065	.110	−.018	.696	.368]
		Max. Dev.	−.002	±.002	−.023	−.004	−.011	+.008	±.003	+.017	+.002	−.005	−.003	−.003	±.002	−.015	±.004	−.001	−.115	+.030
No. 11[b]	5	Mean	.088	.167	.546	.229	1.043	.180	.033	.586	.148	.095	−.011	.164	.196	.121	.168	−.011	.851	.527
		Max. Dev.	−.007	−.008	−.018	−.007	+.046	−.017	+.006	+.016	−.008	+.005	±.004	+.007	−.015	+.006	−.015	±.002	−.086	−.015
No. 12[c]	10	Mean	.085	.127	.483	.243	.819	.133	.027	.459	153	.083	.018	.126	.147	.119	.137	.013	.675	.417
		Max. Dev.	+.005	−.033	−.060	−.010	−.021	+.012	+.004	−.056	−.008	−.006	+.005	−.011	+.016	+.006	−.015	±.002	+.233	+.046
No. 13[b]	10	Mean	.078	.156	.551	.237	.961	.160	.035	.575	.144	.098	−.014	.163	.188	.123	.179	−.011	1.105	.592
		Max. Dev.	−.006	−.003	−.009	+.005	+.064	+.010	−.002	−.026	−.005	−.010	±.002	−.007	+.010	+.006	±.006	+.002	+.137	−.014
		Grand Mean	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.518
		Std. Dev. A[e]	.0024	.0040	.0200	.0028	.0153	.0042	.0015	.0097	.0022	.0034	.0021	.0032	.0053	.0023	.0057	.0004	.0232	.0060
		Std. Dev. B[e]	.0082	.0183	.0721	.0139	.0908	.0226	.0080	.0596	.0031	.0137	.0022	.0153	.0279	.0027	.0242	.0041	.1786	.0728
Coefficient of variability for Std. Dev. B, %			9.8	12.4	13.5	6.0	10.0	14.5	24.8	11.0	2.1	14.6	18.5	10.1	15.8	2.3	14.8	4.3	19.1	14.1

TABLE III.—EXPANSIONS FOR AUTOCLAVE TESTS MADE ON 3 DIFFERENT DAYS (*Continued*).

Laboratory	Gage Length, in.		Expansion, per cent For Cement Indicated																
			19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
No. 1[a]	10[d]	Mean	.338	.197	.030	.070	.414	.202	.090	.034	.120	.120	.043	.077	−.001	.044	.010	.056	.039
		Max. Dev	−.015	−.005	−.015	+.008	+.061	−.052	−.008	−.009	−.016	−.013	+.006	−.011	−.002	−.005	−.008	−.010	−.007
No. 2[b]	10	Mean	[.362	.199	.039	.085	.429	.212	.102	.041	.115	.123	.045	.075	−.002	.046	.018	.066	.044]
		Max. Dev	−.008	±.003	±.003	+.007	−.043	−.006	−.008	+.007	±.009	±.002	−.003	±.001	−.006	−.005	−.004	−.013	+.008
No. 3[b]	10	Mean	.318	.196	.027	.081	.476	.203	.102	.033	.111	.126	.047	.070	−.002	.043	.019	.065	.032
		Max. Dev	+.022	+.017	−.003	−.008	+.022	+.011	+.009	±.002	+.003	+.002	±.003	+.007	±.003	−.004	−.004	−.008	−.004
No. 4[b]	10	Mean	.23	.19	.02	.08	.45	.20	.10	.04	.13	.13	.05	.07	.00	.04	.03	.08	.04
		Max. Dev	−.177	+.017	−.013	+.007	±.025	+.028	.00	.00	±.015	+.013	.00	.00	.00	+.020	±.015	±.015	+.017
No. 5[b]	10	Mean	.32	.19	.02	.08	.40	.19	.10	.03	.11	.13	.04	.06	.00	.04	−.01	.06	.03
		Max. Dev	−.018	−.007	+.008	−.008	−.037	.00	−.007	.00	.00	−.008	.00	+.007	−.007	.00	+.007	−.007	+.012
No. 6[b]	10	Mean	.326	.188	.031	.080	.448	.187	.103	.034	.112	.118	.043	.062	−.004	.041	.018	.066	.036
		Max. Dev	−.010	−.007	+.003	±.007	+.025	+.010	−.008	+.004	+.005	+.003	+.002	±.006	−.001	−.003	−.004	+.006	−.004
No. 7[b]	10	Mean	.337	.229	.039	.088	.459	.204	.093	.035	.125	.128	.045	.087	.009	.041	.024	.078	.053
		Max. Dev	+.029	+.013	±.004	+.009	+.046	+.012	±.006	−.003	+.007	−.008	−.010	+.013	+.017	+.019	+.012	+.011	+.024
No. 8[b]	10	Mean	.35	.21	.03	.08	.41	.21	.09	.04	.12	.12	.05	.08	.00	.05	.03	.06	.05
		Max. Dev	+.017	+.012	+.007	−.018	−.060	−.027	±.010	+.067	+.012	−.011	−.007	±.005	+.008	−.007	+.012	−.050	±.005
No. 9[b]	5	Mean	.440	.248	.055	.109	.577	.279	.113	.062	.175	.154	.067	.101	.015	.067	.049	.099	.060
		Max. Dev	−.038	+.020	+.005	±.005	−.009	−.017	+.005	+.012	+.017	+.008	+.005	+.010	+.005	±.003	+.011	+.011	+.010
No. 10[a]	10	Mean	[.285	.176	.031	.074	.529	.180	.073	.030	.098	.105	.035	.067	.005	.036	.014	.051	.038]
		Max. Dev	−.006	+.002	−.001	+.003	−.013	+.008	−.006	−.003	+.005	+.005	+.003	+.003	+.002	+.005	±.008	+.003	+.004
No. 11[b]	5	Mean	.382	.230	.051	.097	.523	.269	.101	.044	.143	.137	.048	.086	.002	.055	.030	.062	.040
		Max. Dev	+.028	−.010	−.004	+.011	+.028	−.012	±.004	−.004	−.019	+.015	+.006	±.010	+.004	+.005	−.009	+.009	±.005
No. 12[c]	10	Mean	.267	.168	.030	.084	.404	.181	.112	.034	.106	.124	.043	.061	−.001	.040	.015	.074	.039
		Max. Dev	+.045	+.018	+.005	−.011	−.052	+.040	±.004	±.002	+.011	+.005	±.001	+.005	±.001	±.002	+.004	±.002	−.002
No. 13[b]	10	Mean	.376	.220	.039	.085	.583	.242	.094	.034	.128	.126	.049	.085	.005	.052	.019	.073	.038
		Max. Dev	+.010	−.009	+.003	±.005	+.065	−.006	−.003	±.002	±.003	+.007	+.003	±.002	−.001	±.001	±.003	−.002	+.001
		Grand Mean	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041
		Std. Dev. A[e]	.0056	.0029	.0021	.0030	.0100	.0053	.0021	.0071	.0026	.0028	.0018	.0022	.0022	.0042	.0027	.0062	.003
		Std. Dev. B[e]	.0621	.0240	.0109	.0116	.0690	.0110	.0085	.0107	.0200	.0110	.0080	.0132	.0063	.0100	.0144	.0200	.0108
Coefficient of variability for Std. Dev. B—%			18.5	11.7	31.1	13.6	14.8	5.1	8.6	28.1	16.0	8.6	17.0	12.4	300.0	21.5	69.2	28.8	26.4

[a] Autoclaves used by these laboratories were heated by gas.
[b] Cenco-Menzel autoclave used in tests by these laboratories.
[c] Autoclave, 18 by 36 in., heated by gas, used by this laboratory.
[d] Special ball reference points used.
[e] Std. Dev. A is the standard deviation of specimens from the mean of a round (batch). Std. Dev. B is the standard deviation of specimens from the general mean.

TABLE IV.—EXPANSIONS FOR AUTOCLAVE TESTS MADE UNDER DIFFERENT CONDITIONS.

Specimens 1 by 1-in. cross-section. Gage length 10 in., except for laboratories Nos. 9 and 11 which used bars having a gage length of 5 in.
Each value of expansion (minus sign indicates contraction) is the mean of 2 bars made from a single batch, except as noted.

NOTE.—To facilitate comparisons, the grand average expansions (from Table III) for bars of normal consistency subjected to the 5-hr. cycle (3 hr. at 420 F.) are given below the average expansions for each condition of test.

Laboratory	Expansion for Cement Indicated, per cent																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
3 HR. IN AUTOCLAVE (1 HR. AT 420 F.); A.S.T.M. NORMAL CONSISTENCY																																			
No. 1.	.040	.067	.127	.110	.331	.050	.007	.260	.085	.043	−.014	.123	.056	.046	.061	−.017	.185	.214	.151	.100	.016	.033	.151	.073	.050	.014	.053	.070	.020	.044	−.004	.025	−.010	.024	.033
No. 2.	.040	.058	.136	.142	.336	.050	.006	.172	.094	.040	−.030	.119	.057	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 3.																																			
No. 4.	.05	.075	.175	.16	.39	.06	.01	.20	.09	.05	−.02	.125	.06	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 5.	.04	.09	.17	...	...	...	...	...	...	...	...	...	...	...	.07	−.02	.22	.26	.15	.10	.01	.04	.16	.06	...	...	...	...	...	...	...	...	...	...	...
No. 6.	.042	.066	.124	...	...	...	...	...	...	...	...	...	...	...	.069	−.021	.155	.221	.142	.091	.017	.040	.166	.064	...	...	...	...	...	...	...	...	...	...	...
No. 7.	.050	.105	.225	...	...	...	...	...	...	...	...	...	...	...	.085	−.006	.236	.317	.181	.131	.029	.052	.178	.076	...	...	...	...	...	...	...	...	...	...	...
No. 8.	.06	.10	.16	...	...	...	...	...	...	...	...	...	...	...	.08	−.01	.19	.21	.16	.11	.03	.05	.17	.07	...	...	...	...	...	...	...	...	...	...	...
No. 9.	.061	.088	.181	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.028	.076	.093	.039	.059	.001	.035	.012	.049	.048
No. 10.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 11.	.045	.091	.181	.147	.460	.063	.011	.276	.096	.081	−.016	.159	.061	.069	.082	−.019	.243	.265	.245	.125	.030	.046	.191	.091	.053	.021	.062	.087	.030	.049	−.008	.029	.001	.035	.036
No. 12.	.052	.071	.154	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.024	.065	.092	.023	.048	−.003	.029	−.002	.041	.038
No. 13.	.056	.086	.162	.152	.334	.064	.017	.208	.094	.051	−.024	.126	.062	.058	.083	−.016	.224	.282	.190	.105	.027	.042	.200	.082	.064	.022	.061	.085	.026	.048	−.003	.034	.009	.040	.042
Avg...	.049	.082	.163	.142	.370	.057	.010	.223	.092	.053	−.021	.130	.059	.058	.076	−.016	.208	.253	.174	.109	.023	.043	.174	.074	.056	.022	.063	.085	.028	.050	−.003	.030	.002	.038	.039
Grand Avg. (Table III)..	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.516	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041
20 HR. IN AUTOCLAVE (18 HR. AT 420 F.); A.S.T.M. NORMAL CONSISTENCY																																			
No. 1.	.088	.179	.878	.280	3.12	.345	.080	.637	.175	.272	.018	.190	.675	.157	.316	.005	2.5	.760	.427	.280	.078	.246	.623	.333	.110	.123	.244	.189	.066	.118	.030	.091	.098	.175	.070
No. 2.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 3.																																			
No. 4.	.095	.17	1.07	.315	3.725[a]	.39	.095	.70	.20	.295	.02	.205	.645	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 5.	.10	.20	1.04	...	...	...	...	...	...	...	...	...	...	...	.35	.01	1.26	.82	.42	.30	.09	.28	.76	.35	...	...	...	...	...	...	...	...	...	...	...
No. 6.	.098	.177	.965	...	4.1	...	...	...	...	...	...	...	...	...	.336	.006	1.240	.886	.411	.292	.085	.277	.707	.343	...	...	...	...	...	...	...	...	.109	.183	...
No. 7.	.118	.213	1.019	...	...	...	...	...	...	...	...	...	...	...	.362	.019	1.375	.819	.416	.315	.093	.275	.696	.377	...	...	...	...	...	...	...	...	...	...	...
No. 8.	.10	.18	.92	...	...	...	...	...	...	...	...	...	...	...	.32	.02	1.20	.79	.46	.29	.10	.26	.69	.30	...	...	...	...	...	...	...	...	...	...	...
No. 9.	.112	.210	1.074	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 10.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.164	.297	.265	.092	.150	.052	.114	.145	.222	.076
No. 11.	.109	.212	1.073	.334	3.701	397	.113	.773	.211	.302	.030	.228	.613	.197	.371	.022	1.834	.894	.493	.312	.101	.278	.728	.417	.140	.146	.297	.258	.089	.133	.049	.111	.137	.201	.079
No. 12.	.107	.179	1.078	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.143	.279	.250	.075	.121	.033	.085	.086	.182	.069
No. 13.	.108	.204	1.060	.330	3.668	.394	.108	.742	.209	.330	.026	.220	.611	.198	.382	.016	1.804	.843	.466	.306	.099	.283	.707	.400	.146	.149	.285	.250	.088	.140	.048	.106	.104	.167	.070
Avg...	.104	.192	1.018	.315	3.663	.382	.099	.713	.199	.300	.024	.211	.636	.184	.348	.014	1.602	.830	.442	.299	.092	.271	.701	360	.132	.145	.280	.242	.082	.132	.042	.101	.113	.188	.073
Grand Avg. (Table III)..	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.516	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041

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[a] Bars badly warped.
[b] Water used was A.S.T.M. Normal Consistency plus 10 per cent.
[c] Data from Table III.
[d] One bar.
A, B Values are for a single bar; see text for detailed procedure.

TABLE IV.—*Continued.*

Specimens 1 by 1-in. cross-section. Gage length 10 in., except for laboratories 9 and 11 which used bars having a gage length of 5 in.
Each value of expansion (minus sign indicates contraction) is the mean of 2 bars made from a single batch, except as noted.
Note.—To facilitate comparisons, the grand average expansions (from Table III) for bars of normal consistency subjected to the 5-hr. cycle (3 hr. at 420 F.) are given below the average expansions for each condition of test.

Laboratory	Expansion for Cement Indicated, per cent																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MIXING WATER $27\frac{1}{2}$ PER CENT BY WEIGHT; 5 HR. IN AUTOCLAVE (3 HR. AT 420 F.)																																			
No. 1.	.079	.157	.737	.218	1.054	.166	.036	.518	.132	.100	−.005	.156	.242	.112	.180	−.006	1.449[a]	.560	.376	.217	.040	.085	.479	.240	.097	.042	.118	.116	.047	.080	.005	.056	.005	.051	.037
No. 2.	.083	.171	.692	.216	1.198	.192	.038	.576	.138	.090	−.007	.158	.230	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 3.	.057	.161	.698	.229	1.116	.186	.044	.552	.144	.104	−.006	.163	.245																						
No. 4.	.07	.145	.74	.235	1.205	.17	.04	.52	.16	.105	−.005	.17	.265																						
No. 5.	.08	.17	.83	....	....	....	....	....	....	....	....	....	....	....	.18	−.01	1.27	.64	.37	.21	.04	.09	.47	.22	....	....	....	....	....	....	....	....	....	....	....
No. 6.	.076	.145	.631	....	....	....	....	....	....	....	....	....	....	....	.175	−.008	1.122	.623	.398	.181	.035	.083	.365	.239	....	....	....	....	....	....	....	....	....	....	....
No. 7.	.087	.160	.727	....	....	....	....	....	....	....	....	....	....	....	.220	−.035	1.377	.677	.443	.267	.055	.116	.604	.265	....	....	....	....	....	....	....	....	....	....	....
No. 8.	.08	.13	.71	....	....	....	....	....	....	....	....	....	....	....	.18	.00	.95	.59	.40	.22	.04	.09	.46	.25	....	....	....	....	....	....	....	....	....	....	....
No. 9.	.103	.186	.769	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.058	.151	.156	.069	.101	.011	.064	.017	.069	.049
No. 10.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 11.	.078	.166	.761	.238	1.071	.198	.038	.634	.152	.117	−.003	.175	.293	.116	.200	−.007	1.361	.678	.503	.246	.047	.102	.542	.290	.102	.044	.159	.160	.052	.087	.003	.061	.015	.055	.036
No. 12.	.065	.096	.349	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.044	.104	.127	.051	.055	.001	.041	.003	.054	.042
No. 13.	.084	.186	.806	.237	1.193	.190	.044	.607	.152	.122	−.004	.176	.270	.121	.220	−.006	1.351	.654	.451	.230	.045	.092	.647[b]	.274	.094	.040	.138	.138	.056	.096	.010	.060	.041[b]	.094[b]	.050[b]
Avg. . .	.079	.156	.704	.229	1.140	.184	.040	.568	.146	.106	−.005	.166	.257	.116	.194	−.010	1.269	.631	.420	.224	.043	.094	.510	.254	.098	.046	.134	.139	.055	.084	.006	.056	.016	.064	.042
Grand Avg. (Table III). .	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.516	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041
MIXING WATER 40 PER CENT BY WEIGHT; 5 HR. IN AUTOCLAVE (3 HR. AT 420 F.)																																			
No. 1.	.092	.187	1.066	.245	1.188	.183	.055	.656	.160	.143	.008	.185	.410	.114	.195	.003	1.180[a]	.877	.494	.224	.063	.118	.533	.265	.120	.056	.148	.135	.057	.094	.016	.070	.049	.084	.047
No. 2.	.088	.181	1.450	.253	1.310	.198	.078	.675	.174	.170	−.003	.196	.472	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 3.	.096	.209	1.380	.285	1.646	.222	.071	.768	.187	.185	.011	.218	.479																						
No. 4.	.09	.185	1.315	.275	1.52	.22	.07	.775	.175	.17	.00	.22	.525																						
No. 5.	10	.20	1.40	....	....	....	....	....	....	....	....	....	....	....	.22	.00	1.33	1.06	.54	.24	.07	.14	.59	.29	....	....	....	....	....	....	....	....	....	....	....
No. 6.	.089	.203	1.141	....	....	....	....	....	....	....	....	....	....	....	.211	.006	1.342	.959	.559	.236	.059	.145	.544	.285	....	....	....	....	....	....	....	....	....	....	....
No. 7.	.102	.207	1.367	....	....	....	....	....	....	....	....	....	....	....	.264	.014	1.442	1.299	.572	.273	.080	.163	.620	.314	....	....	....	....	....	....	....	....	....	....	....
No. 8.	.09	.20	1.30	....	....	....	....	....	....	....	....	....	....	....	.21	.02	1.37	.99	.52	.22	.08	.15	.52	.24	....	....	....	....	....	....	....	....	....	....	....
No. 9.	.107	.211	1.559	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.081	.209	.203	.080	.124	.031	.101	.074	.123	.068
No. 10.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 11.	.099	.202	1.313	.290	1.540	.222	.068	.731	.199	.194	.011	.229	.545	.154	.241	−.007	1.532	1.058	.560	.234	.059	.167	.641	.323	.120	.072	.176	.157	.059	.104	−.005	.065	.039	.095	.039
No. 12.	.090	.175	.957	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.056	.155	.158	.057	.090	.012	.067	.047	.094	.051
No. 13.	.097	.214	1.272	.268	1.506	.222	.070	.791	.184	.186	.007	.228	.514	.142	.232	.005	1.423	1.046	.565	.232	.072	.154	.587	.324	.132	.070	.178	.184	.075	.110	.021	.080	.053	.110	.061
Avg. . .	.095	.198	1.293	.269	1.452	.211	.069	.733	.180	.175	.006	.213	.491	.137	.225	.006	1.374	1.041	.544	.237	.069	.148	.576	.292	.124	.067	.173	.167	.066	.104	.015	.077	.052	.101	.053
Grand Avg. (Table III). .	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.516	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041

[a] Bars badly warped.

[b] Water used was A.S.T.M. Normal Consistency plus 10 per cent.

[c] Data from Table III.

[d] One bar.

A, B Values are for a single bar; see text for detailed procedure.

TABLE IV.—*Continued.*

Specimens 1 by 1-in. cross-section. Gage length 10 in., except for laboratories 9 and 11 which used bars having a gage length of 5 in.
Each value of expansion (minus sign indicates contraction) is the mean of 2 bars made from a single batch, except as noted.

NOTE.—To facilitate comparisons, the grand average expansions (from Table III) for bars of normal consistency subjected to the 5-hr. cycle (3 hr. at 420 F.) are given below the average expansions for each condition of test.

Laboratory	Expansion for Cement Indicated, per cent																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MODIFIED PROCEDURE (SEE TEXT); 5 HR. IN AUTOCLAVE (3 HR. AT 420 F.)																																			
No. 1.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 2.	.084	.138	.434	.220	.790	.148	.034	.448	.152	.086	−.003	.144	.193	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 3.																																			
No. 4.	.085	.145	.46	.22	.785	.125	.03	.485	.16	.105	.00	.155	.17																						
No. 5.	.09	.16	.66	...	...	...	...	...	...	...	...	...	...	...	.17	.00	.94	.56	.35	.20	.04	.09	.41	.20	...	...	...	...	...	...	...	...	...	...	...
No. 6.	.090	.139	.392	...	...	...	...	...	...	...	...	...	...	...	.153	−.003	.682	.501	.328	.211	.030	.085	.510	.220	...	...	...	...	...	...	...	...	...	...	...
No. 7.	.091	.167	.572	...	...	...	...	...	...	...	...	...	...	...	.207	.009	1.125	.679	.372	.247	.046	.252	.457	.211	...	...	...	...	...	...	...	...	...	...	...
No. 8.	.14	.16	.51	...	...	...	...	...	...	...	...	...	...	...	.14	.00	.84	.56	.41	.23	.05	.11	.59	.28	...	...	...	...	...	...	...	...	...	...	...
No. 9.	.086	.144	.546	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.056	.143	.146	.073	.099	.013	.055	.041	.093	.048
No. 10.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 11.	.082	.168	.632	.230	1.071	.186	.035	.529	.146	.110	−.003	.174	.201	.126	.207	−.003	1.058	.618	.493	.236	.048	.111	.560	.298	.105	.047	.149	.156	.058	.078	.002	.057	.031	.076	.048
No. 12.	.075	.127	.407	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.050	.128	.142	.051	.076	.005	.047	.023	.076	.044
No. 13A	.084	.161	.553	.244	.833	.154	.035	.639	.154	.101	−.008	.162	.181	.134	.176	−.004	1.045	.589	.402	.228	.039	.086	.552	.259	.102	.042	.129	.134	.056	.089	.005	.056	.032	.083	.047
No. 13B	.088	.162	.562	.243	.961	.164	.039	.621	.155	.102	−.010	.162	.184	.133	.181	−.003	1.077	.596	.407	.232	.044	.093	.558	.263	.106	.044	.133	.135	.056	.088	.004	.051	.039	.084	.044
Avg...	.091	.151	.517	.229	.886	.155	.034	.523	.153	.100	−.004	.159	.186	.130	.176	.000	.951	.585	.393	.226	.043	.123	.514	.245	.105	.049	.138	.145	.060	.085	.006	.053	.033	.082	.047
Grand Avg. (Table III)..	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.516	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041
TEST SPECIMEN—5-IN. GAGE LENGTH; 5 HR. IN AUTOCLAVE (3 HR. AT 420 F.)																																			
No. 1.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 2.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 3.																																			
No. 4.	.085	.13	.505	.23	1.09^d	.15	.03	.63	.155	.095	−.01	.16	.195																						
No. 5.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 6.	.083	.164	.498	...	...	...	...	...	...	...	...	...	...	...	.170	−.011	.815	.556	.394	.228	.043	.092	.584	.228	...	...	...	...	...	...	...	...	...	...	...
No. 7.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 8.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 9^c	.096	.179	.612	.253	1.005	.197	.052	.633	.162	.125	.003	.171	.220	.131	.206	−.002	1.102	.614	.440	.248	.055	.109	.577	.279	.113	.062	.175	.154	.067	.101	.015	.067	.049	.099	.060
No. 10.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 11^c	.088	.167	.546	.229	1.043	.180	.033	.586	.148	.095	−.011	.164	.196	.121	.168	−.011	.851	.527	.382	.230	.051	.097	.523	.269	.101	.044	.143	.137	.048	.086	.002	.055	.030	.062	.040
No. 12.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
No. 13.	.081	.140	.496	.241	.846	.134	.031	.537	.160	.110	−.011	.166	.199	.130	.197	.00	.962	.596	.404	.244	.046	.094	.604	.280	.098	.051	.164	.152	.059	.090	.006	.060	.031	.078	.040
Avg...	.087	.156	.531	.238	.996	.165	.037	.596	.156	.106	−.007	.165	.202	.127	.185	−.006	.933	.573	.405	.239	.049	.098	.572	.264	.104	.052	.161	.148	.058	.092	.008	.061	.037	.080	.047
Grand Avg. (Table III)..	.083	.148	.532	.233	.912	.156	.032	.538	.145	.094	−.012	.151	.177	.117	.163	−.010	.935	.516	.335	.206	.035	.085	.467	.215	.100	.038	.125	.128	.047	.076	.002	.046	.021	.069	.041

[a] Bars badly warped.
[b] Water used was A.S.T.M. Normal Consistency plus 10 per cent.
[c] Data from Table III.
[d] One bar.

A, B Values are for a single bar; see text for detailed procedure.

(Fig. 3 (*c*) and Table VI) shows that they differed but little. In laboratory 13 two modified procedures designated as "A" and "B" were used and no significant differences in the expansion values were found. Modified procedure "A" was the same as the normal 5-hr. procedure except that the 1-hr. soaking period at the beginning of the test was omitted, the specimens being measured and placed in the autoclave immediately upon removal from the molds after 24 hr. in the moist closet. Modified procedure "B" was the same as "A" except that the 30-min. period of cooling (15 min. in the autoclave and 15 min. in air) following autoclaving was omitted, that is, the specimens were removed from the autoclave immediately when it was opened, placed in boiling water, cooled to 70 F. in 30 min. and then measured. If the normal 5-hr. exposure were modified to include the changes made under procedure "B," the total time of test could be reduced from the 7 hr. usually required to about 5½ hr. On the basis of the results secured by those laboratories which used the modified procedures, it appears

TABLE V.—EXPANSIONS FOR REPEAT TESTS.

Autoclave specimens 1 by 1 in. in cross-section; gage length of bars for laboratory Nos. 4 and 13, 10 in.; for laboratory 11, 5 in.

Cement	Expansions for Repeat Autoclave Tests—5 hr. in Autoclave (3 hr. at Max. Temp. of 420 F.) for Each Exposure, per cent												
	Second Exposure—10 hr. Total							Third Exposure—15 hr. Total					
	Lab. No. 4 Avg. 2 Tests	Lab. No. 11 (3 batches, 2 tests each)				Lab. No. 13 One Test	Avg. for 3 Labs.	Lab. No. 4 Avg. 2 Tests	Lab. No. 11 (3 batches, 2 tests each)				Avg. for 2 Labs.
		1	2	3	Avg.				1	2	3	Avg.	
No. 1	0.099	0.101	0.102	0.103	0.102	0.095	0.099	0.109	0.111	0.115	0.114	0.113	0.111
No. 2	0.182	0.201	0.199	0.191	0.197	0.197	0.192	0.151	0.220	0.221	0.207	0.216	0.183
No. 3	1.038	0.870	0.970	0.932	0.924	0.804	0.922	1.345	1.046	1.168	1.122	1.112	1.228
No. 4	0.279	0.287	0.288	0.283	0.286	0.290	0.285	0.327	0.341	0.350	0.339	0.343	0.335
No. 5	1.497	2.880	2.825	2.227	2.644	1.498	1.880	3.118	4.394	4.660	3.700	4.251	3.685
No. 6	0.332	0.324	0.331	0.303	0.319	0.306	0.319	0.414	0.392	0.394	0.363	0.383	0.398
No. 7	0.064	0.052	0.049	0.061	0.054	0.056	0.058	0.085	0.070	0.066	0.076	0.071	0.078
No. 8	0.717	0.751	0.721	0.756	0.743	0.756	0.739	0.787	0.826	0.798	0.831	0.818	0.802
No. 9	0.193	0.194	0.209	0.195	0.199	0.194	0.195	0.234	0.240	0.257	0.237	0.245	0.240
No. 10	0.208	0.176	0.172	0.178	0.175	0.166	0.184	0.281	0.239	0.230	0.237	0.235	0.258
No 11	0.000	0.001	0.003	−0.003	0.000	−0.004	−0.001	0.010	0.013	0.016	0.010	0.013	0.012
No. 12	0.177	0.190	0.200	0.197	0.196	0.199	0.191	0.203	0.219	0.231	0.225	0.225	0.214
No. 13	0.445	0.407	0.420	0.411	0.413	0.381	0.413	0.729	0.579	0.575	0.553	0.569	0.649
No. 14	0.162	0.168	0.171	0.159	0.166	0.173	0.167	0.197	0.210	0.213	0.197	0.207	0.202
No. 15	0.284	0.263	0.286	0.278	0.276	0.304	0.354	0.347	0.328	0.344	0.337	0.336	0.342
No. 16	−0.005	−0.004	−0.004	−0.003	−0.004	0.001	−0.003	0.000	0.007	0.006	0.006	0.006	0.003
No. 17	1.115	1.137	1.219	1.314	1.223	1.460	1.267	1.287	1.287	1.355	1.454	1.365	1.326
No. 18	0.772	0.700	0.704	0.718	0.706	0.771	0.750	0.899	0.785	0.792	0.802	0.792	0.846
No. 19	0.440	0.470	0.510	0.480	0.487	0.499	0.475	0.366	0.517	0.552	0.528	0.532	0.449
No. 20	0.278	0.290	0.300	0.298	0.296	0.301	0.292	0.311	0.324	0.333	0.329	0.329	0.320
No. 21	0.052	0.072	0.072	0.069	0.071	0.068	0.064	0.066	0.089	0.082	0.084	0.085	0.076
No. 22	0.158	0.157	0.148	0.156	0.154	0.162	0.158	0.214	0.205	0.177	0.197	0.193	0.204
No. 23	0.823	0.702	0.731	0.694	0.709	0.777	0.770	0.872	0.776	0.784	0.743	0.768	0.820
No. 24	0.337	0.363	0.371	0.381	0.372	0.357	0.355	0.388	0.418	0.420	0.439	0.426	0.407
No. 25	0.141	0.140	0.135	0.129	0.135	0.138	0.138	0.169	0.168	0.158	0.156	0.161	0.165
No. 26	0.086	0.071	0.075	0.073	0.073	0.074	0.078	0.112	0.097	0.091	0.099	0.096	0.104
No. 27	0.229	0.226	0.238	0.218[a]	0.229	0.221	0.226	0.272	0.271	0.281	0.261[a]	0.263	0.268
No. 28	0.211	0.204	0.213	0.185	0.201	0.201	0.204	0.252	0.240	0.250	0.222	0.237	0.245
No. 29	0.064	0.072	0.068	0.057	0.066	0.069	0.066	0.072	0.083	0.081	0.072	0.079	0.076
No. 30	0.103	0.105	0.116	0.101	0.107	0.114	0.108	0.115	0.122	0.135	0.116	0.124	0.120
No. 31	0.011	0.012	0.017	0.011[a]	0.014	0.017	0.014	0.016	0.022	0.029	0.020[a]	0.024	0.020
No. 32	0.045	0.076	0.073	0.067	0.072	0.070	0.062	0.057	0.093	0.090	0.084	0.089	0.073
No. 33	0.050	0.038	0.036	0.043	0.039	0.056	0.048	0.067	0.044	0.039	0.050	0.044	0.056
No. 34	0.112	0.078	0.085	0.087	0.083	0.118	0.104	0.135	0.089	0.095	0.095	0.093	0.114
No. 35	0.048	0.046	0.056	0.061	0.054	0.046	0.049	0.055	0.055	0.073	0.076	0.068	0.062

[a] One bar.

that this saving of 1½ hr. could be made without any significant effect on the measured expansions.

Comparison of 5- and 10-in. Bars.—Laboratories 9 and 11, which regularly use bars having an effective gage length of 5 in., used this length in all of the tests of this series. A few other laboratories also made tests using the shorter bar in order to determine whether results obtained by the two sizes would be of the same order. It should be noted that the effective gage length is considered to be the distance between the inner ends of the metal reference points. Thus a bar 11¼-in. long is assumed to have an effective gage length of 10 in. if the inserts extend ⅝-in. into the specimen. Similarly a 6¼-in. bar is assumed to have an effective gage length of 5 in. Laboratory 1 used ⅜-in. diameter spherical inserts embedded $\frac{3}{16}$-in. to which were welded short pieces of straight rod extending into the bar about ½ in., the length of the bar being 10 in. In this laboratory the gage length was con-

TABLE VI.—AVERAGE AUTOCLAVE EXPANSIONS FOR VARIOUS METHODS OF TEST.

Data from Tables III, IV, and V.

Bars were made of neat cement paste of A.S.T.M. normal consistency and were exposed in autoclave for a total of 5 hr. unless otherwise noted.

Cement	Expansion (minus sign indicates contraction), per cent:								
	Total Time in Autoclave, hr.					Mixing Water, per cent by weight		Modified Procedure (3-10)[a]	Short Bar 5-in. Gage Length (3-5)[a]
	3 (3-11)[a]	5 (11)[a]	20 (3-10)[a]	10 Double 5h. Exp. (3)[a]	15 Triple 5h. Exp. (2)[a]	27½ (3-12)[a]	40 (3-12)[a]		
No. 1	0.049	0.083	0.104	0.099	0.111	0.079	0.095	0.091	0.087
No. 2	0.082	0.148	0.192	0.192	0.183	0.156	0.198	0.151	0.156
No. 3	0.163	0.532	1.018	0.922	1.228	0.704	1.293	0.517	0.531
No. 4	0.142	0.233	0.315	0.285	0.335	0.229	0.269	0.229	0.238
No. 5	0.370	0.912	3.663	1.880	3.685	1.140	1.452	0.886	0.996
No. 6	0.057	0.156	0.382	0.319	0.398	0.184	0.211	0.155	0.165
No. 7	0.010	0.032	0.099	0.058	0.078	0.040	0.069	0.034	0.037
No. 8	0.228	0.538	0.713	0.739	0.802	0.568	0.733	0.523	0.596
No. 9	0.092	0.145	0.199	0.195	0.240	0.146	0.180	0.153	0.156
No. 10	0.053	0.094	0.300	0.184	0.258	0.106	0.175	0.100	0.106
No. 11	−0.021	−0.012	0.024	−0.001	0.012	−0.005	0.006	−0.004	−0.007
No. 12	0.130	0.151	0.211	0.191	0.214	0.166	0.213	0.159	0.165
No. 13	0.059	0.177	0.636	0.413	0.649	0.257	0.491	0.186	0.202
No. 14	0.058	0.117	0.184	0.167	0.202	0.116	0.137	0.130	0.127
No. 15	0.076	0.163	0.348	0.354	0.342	0.194	0.225	0.176	0.185
No. 16	−0.016	−0.010	0.014	−0.003	0.003	−0.010	0.006	0.000	−0.006
No. 17	0.208	0.935	1.602	1.267	1.326	1.269	1.374	0.951	0.933
No. 18	0.253	0.518	0.830	0.750	0.846	0.631	1.041	0.585	0.573
No. 19	0.174	0.335	0.442	0.475	0.449	0.420	0.544	0.393	0.405
No. 20	0.109	0.206	0.299	0.292	0.320	0.224	0.237	0.226	0.239
No. 21	0.023	0.035	0.092	0.064	0.076	0.043	0.069	0.043	0.049
No. 22	0.043	0.085	0.271	0.158	0.204	0.094	0.148	0.123	0.098
No. 23	0.174	0.467	0.701	0.770	0.820	0.510	0.576	0.514	0.572
No. 24	0.074	0.215	0.360	0.355	0.407	0.254	0.292	0.245	0.264
No. 25	0.056	0.100	0.132	0.138	0.165	0.098	0.124	0.105	0.104
No. 26	0.022	0.038	0.145	0.078	0.104	0.046	0.067	0.049	0.052
No. 27	0.063	0.125	0.280	0.226	0.268	0.134	0.173	0.138	0.161
No. 28	0.085	0.128	0.242	0.204	0.245	0.139	0.167	0.145	0.148
No. 29	0.028	0.047	0.082	0.066	0.076	0.055	0.066	0.060	0.058
No. 30	0.050	0.076	0.132	0.108	0.120	0.084	0.104	0.085	0.092
No. 31	−0.003	0.002	0.042	0.014	0.020	0.006	0.015	0.006	0.008
No. 32	0.030	0.046	0.101	0.062	0.073	0.056	0.077	0.053	0.061
No. 33	0.002	0.021	0.113	0.048	0.056	0.016	0.052	0.033	0.037
No. 34	0.038	0.069	0.188	0.104	0.114	0.064	0.101	0.082	0.080
No. 35	0.039	0.041	0.073	0.049	0.062	0.042	0.053	0.047	0.047

[a] Values in parentheses are the number of laboratories reporting.

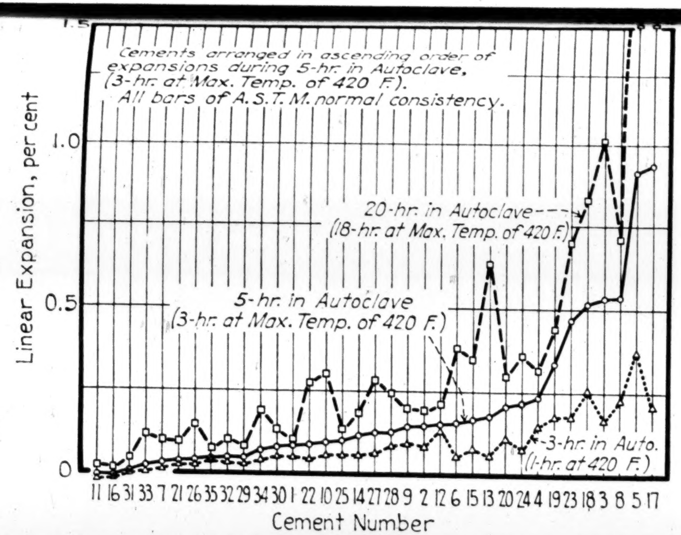

FIG. 1 (*a*).—Effect of Duration of Exposure in Autoclave on Linear Expansion of Neat Cement Bars.

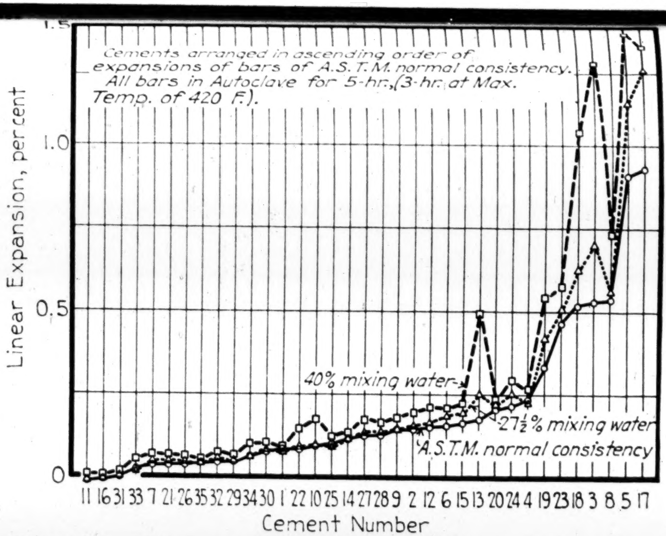

FIG. 2 (*a*).—Effect of Amount of Mixing Water on Linear Expansion of Neat Cement Bars.

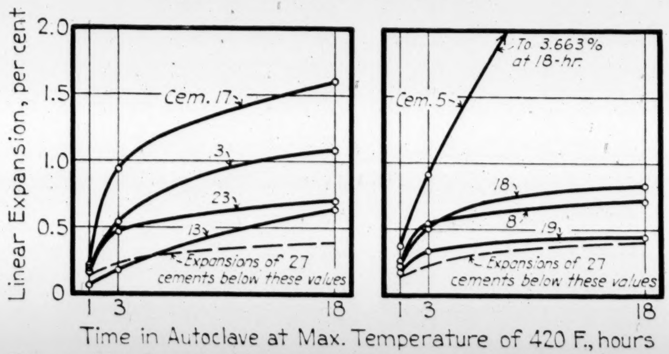

FIG. 1 (*b*).—Length Changes of Neat Cement Bars During Autoclaving as Affected by Time at 420 F.

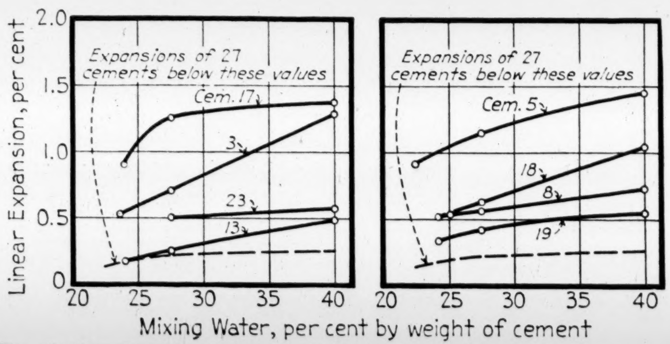

FIG. 2 (*b*).—Length Changes of Neat Cement Bars During Autoclaving as Affected by Amount of Mixing Water.

Specimen tested at age of 1 day upon removal from molds.

sidered to be the length of the bar or 10 in.

In Fig. 3(*d*) the average results for bars of 5-in. gage length are plotted against those of bars of 10-in. gage length. It will be seen that some difference exists between the results obtained with the two sizes of bar. In general the shorter bar shows higher expansions. This seems to indicate that the gage length is not strictly the distance between the ends of the metal inserts as is assumed. What should be considered the effective gage length would not be important if all test bars were of the same length and the reference points extended into the bar the same distance. This rather points to the desirability of adhering to a fixed length and a standard type of insert and depth of embedment.

Effect of Repeated Exposure.—Laboratories 4, 11 and 13 subjected bars to two 5-hr. cycles and laboratories 4 and 11 to three 5-hr. cycles. The results are given in Table V. It will be observed that the total expansions for the second cycle are in general about one and one-half times as great as those obtained for a single exposure. After the third cycle the total expansions were still higher, but it should be noted that in no case did disintegration of the bars occur. Another point of interest is that where the expansion in the normal 5-hr. exposure was less than about 0.5 per cent, neither the triple 5-hr. nor the single 20-hr. exposure produced a total expansion of 1 per cent. The expansions after the triple cycle (9 hr. total time at 420 F.) are in most cases of approximately the same magnitude as the expansions during a single 20-hr. cycle, even though in the latter the total time (18 hr. at maximum temperature of 420 F.) was twice as long.

Weight Changes.—Laboratories 8 and 13 reported weights of the bars before and after autoclaving. The data showed that all specimens having a relatively low expansion showed a loss in weight during autoclaving, while those showing relatively high expansions showed a gain in weight. A close correlation between change in weight and expansion was not found.

Uniformity of Tests—In considering the autoclave test as an acceptance test of cement, it was desired to obtain information on the uniformity to be expected in repeat tests on the same cement in a given laboratory and in different laboratories. It was also desired to know how the autoclave test compared with strength tests, such as the 2-in. mortar cube test, as to agreement between results on the two bases mentioned.

In order to obtain information on these points, the data from Table III for all laboratories reporting complete results for the normal 5-hr. test (3 hr. at 420 F.) were analyzed statistically to determine standard deviations for: (1) individual bars from the mean of a given laboratory and (2) the mean of a given laboratory from the general mean for all laboratories. From these deviations a straight-line equation was derived which gave the relation between standard deviation and the mean expansion for all cements. From this equation using a multiplier obtained from Pierce's probability table[1] the spreads in results given in Fig. 4 were obtained. Figure 4 shows that in a series of tests on the same cement in a given laboratory, 90 per cent of the results would be expected to fall within a narrow range—about 0.03 per cent above or below the mean. If the cement is tested in a group of laboratories, the range within which 90 per cent of the values would be expected to fall is about 0.22 per cent above or below the mean. It is important to note

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[1] A short table of integrals, by Pierce, Ginn and Company, N. Y.

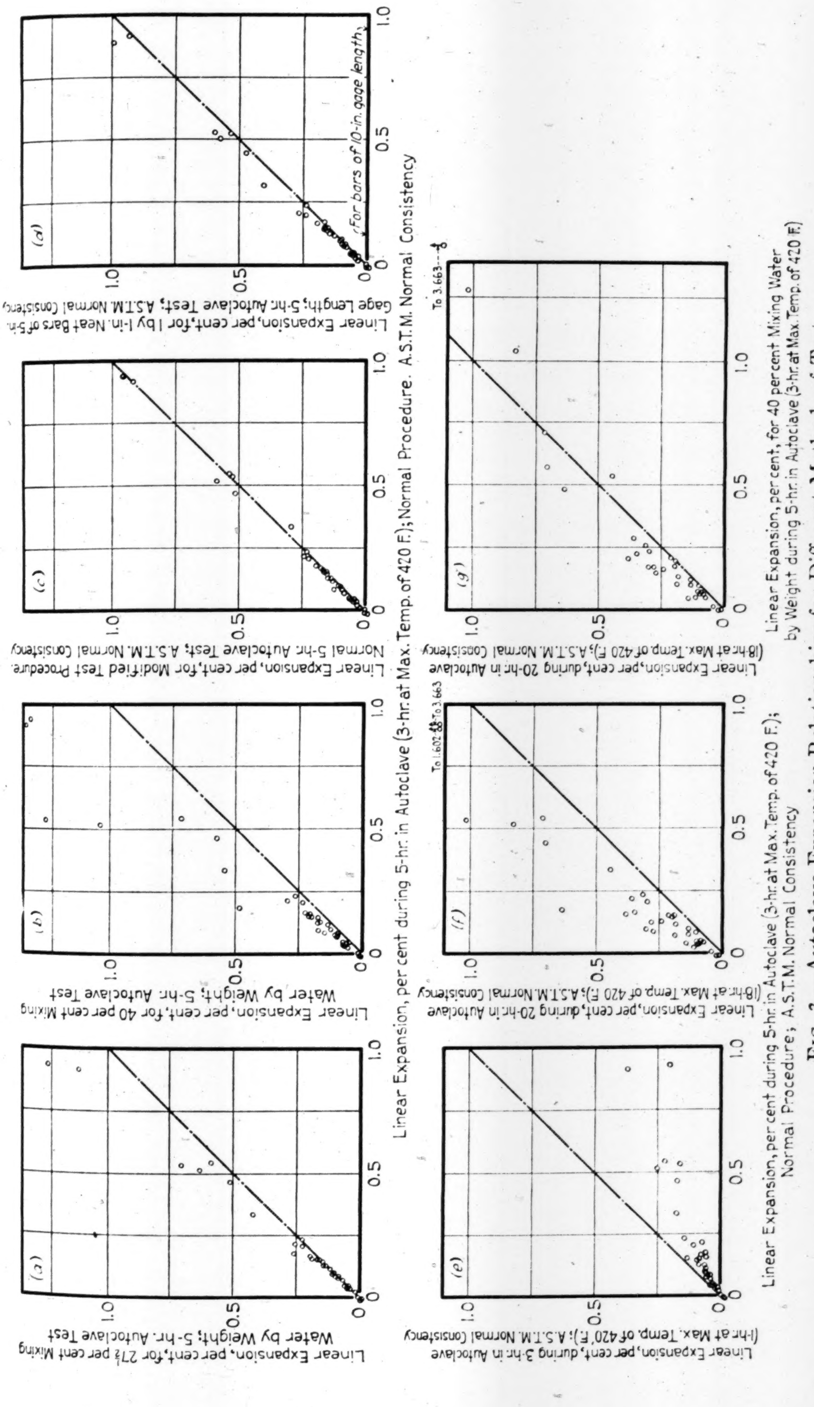

FIG. 3.—Autoclave Expansion Relationships for Different Methods of Test.

Specimens 1 by 1-in. neat cement bars, effective gage length 5 or 10 in.
Specimens tested at age of 1 day upon removal from molds.

that only a few cements had expansions of over 0.5 per cent and of these the one (No. 17) with the highest mean (0.94 per cent) was more erratic both in tests in a given laboratory and in the different laboratories. This contributed significantly to the wide range in expected results from different laboratories. The indications from Fig. 4 are that it is not difficult for laboratories to obtain consistent results on tests made on different days on the same cement. The results of tests between different laboratories, however, are less concordant, and indicate that in order to meet any fixed limit on expansion the cement would have to have an expansion at least 20 per cent below the fixed value in order that its acceptance in tests by any laboratory would be reasonably certain.

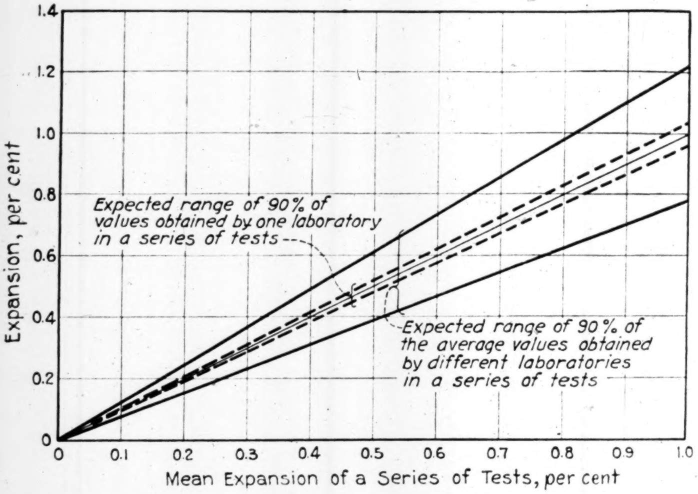

FIG. 4.—Influence of Degree of Expansion on the Uniformity of Autoclave Tests.

In order to compare the autoclave test with the 2-in. mortar cube test as to uniformity in results, data reported by the Working Committee on Plastic Mortar Tests[1] were analyzed. In these tests, 3 cubes were made on 3 days of three mortars, designated as Bates, Pearson, and C109 mixes, and tested at ages of 1, 3, 7 and 28 days. Three portland cements were used, a normal, a high-early-strength, and a moderate-heat cement. Studies of the results for the normal and high-early-strength cements only were made. It was found that the coefficient of variability[2] for the autoclave test was, except for cement No. 17, as low as for the cube test.

PROPOSED METHOD OF TEST

In Appendix B is given a recommended procedure for making autoclave tests of portland cement. This is based on the experience gained in all the tests conducted to date.

Respectfully submitted on behalf of the Working Committee,

H. F. GONNERMAN,
Chairman.

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[1] See Report on Investigation of Pebble Mortars, p. 267.

[2] Coefficient of variability is the standard deviation expressed as a percentage of the mean.

APPENDIX A

OUTLINE OF COOPERATIVE STUDIES OF AUTOCLAVE TESTS OF PORTLAND CEMENT

The instruction for conducting the cooperative studies of the autoclave test is set forth in the following table and in the accompanying description.

Variable	Effective Length of Bar, in.	Consistency	Age at Test, hr.	Time, hr.				Specimens		
				To reach 420 F.	At 420 F.	To Cool to 212 F.	Total	Number from same Batch	Number of Batches	Total for each Cement
Group I.[a]	10 in.	A.S.T.M. normal	24	1	3	1	5[b]	2	3[c]	6
Group II. Time at maximum temperature	10 in.	A.S.T.M. normal	24	1 1	1 18	1 1	3 20	2 2	1 1	2 2
Group III. Consistency	10 in.	$27\frac{1}{2}$ per cent water 40 per cent water	24	1	3	1	5	2	1	4
Group IV.[d] Time to complete test	10 in.	A.S.T.M. normal	24	1	3	1	5	2	1	2
Group V. Size of bar	5 in.	A.S.T.M. normal	24	1	3	1	5	2	1	2
									Grand Total	18

Group VI. Make Standard A.S.T.M. Soundness Tests on each cement.

[a] This group of tests will be used as the basis of comparison of the tests in the other groups.

[b] If time and facilities permit, after completion of test cycle subject the same bars to a second, and if possible, a third test of the same cycle.

[c] One on each of three different days.

[d] Remove specimens from molds and weigh and measure for length immediately, omitting the 1-hr. soaking period in water. Removal from molds and moist closet should be timed so that immediately after weighing and measuring, the specimens can be placed in the autoclave at the age of 24 hr. in a minimum of time. After the 5-hr. period in the autoclave these specimens should be cooled in the regular manner except that the final measuring temperature should be 70 F., the temperature at which the initial readings were made, instead of 80 F.

Preparation of Test Bars.—Mix a neat cement paste of normal consistency in accordance with the methods described in Sections 19 to 22 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation C 77 – 32).[1,2] Immediately after mixing, fill the mold in three layers. Compact each layer with the rubber glove-protected forefinger, working from one end of the mold to the opposite end in 25 strokes (12 strokes for 5-in. bar). Work along the bar and back two times or a total of 4 times for each layer. After the top layer has been compacted, smooth the specimen with a few strokes of the trowel, leaving the paste slightly above the sides of the molds.

Immediately after the mold has been filled, place it in the moist closet or moist room at a temperature of 70 ± 3 F. and a relative humidity of at least 90 per cent. Approximately 2 hr. after molding give the bars the final troweled finish, mark the identifying reference numbers on the surface and continue the

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 9.

[2] Specimens of Group III containing $27\frac{1}{2}$ per cent water to be made in the same manner as that described for specimens of A.S.T.M. normal consistency. For fluid cement-water mixtures containing 40 per cent water the mixing and placing procedure should be as follows: Place water and cement in an 8-in. metal stew pan and allow 1 min. for absorption of water and then mix paste vigorously with an 11-in. metal spoon for 1 min. Fill each mold half full, and then repeat the operation, filling each mold to overflowing, stirring the paste during filling. After filling, tap mold lightly with butt of trowel in order to settle paste in mold.

moist curing. From 22 to 23 hr. after molding remove the bars from the molds and place in water at 80 F. Approximately 1 hr. after removal from molds, surface dry the bars, one at a time, with a cloth and immediately weigh[1] and measure for length in a length comparator. After weighing and measuring, keep the bars in water until placed in the autoclave.

Autoclaving.—At the age of 24 hr. place the bars in the autoclave and heat the water rapidly to bring the temperature of the steam in 1 hr. to 420 F., which corresponds to a gage pressure of 295 lb. per sq. in. Care should be taken to permit the air to escape from the autoclave during heating to 212 F. Maintain the 420 F. temperature for 3 hr. (or for the times indicated in the outline). After the desired period in the autoclave at the 420 F. temperature, shut off the heat supply and allow the autoclave to cool slowly so that the pressure will gradually fall to near atmospheric by the end of 1 hr. At the end of the 1-hr. period, the small pressure remaining should be slowly released through a vent valve until atmospheric pressure is attained. The autoclave should then be opened and the bars allowed to cool for 15 min. in the autoclave, and then 15 min. in air of the laboratory. The bars should then be immersed in water which has been preheated to the temperature of the bars (approximately 150 F.) after cooling in air of laboratory for the 15-min. period indicated above. Gradually cool the water and bars to 80 F. in a 30-min. period, and then surface dry, weigh, and measure the bars for length. Express the change in length during autoclaving, as a percentage of the length before placing in autoclave.

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[1] Weighing recommended for future reference.

APPENDIX B

PROPOSED METHOD OF TEST
FOR
AUTOCLAVE EXPANSION OF PORTLAND CEMENT[1]

This **proposed method** is published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for determining the soundness of portland cement by means of an autoclave test on 1 by 1-in. neat-cement specimens.

Scales

2. (*a*) The scales used in weighing materials for the neat-cement mixes shall conform to the following requirements: On scales in use the tolerance for a load of 1000 g. shall be plus or minus 1.0 g. The tolerance on new scales shall be one-half of this value. The sensibility reciprocal[2] shall not be greater than twice the tolerance.

(*b*) The tolerances on the weights in use in weighing materials for neat-cement mixes shall be as follows:

Weight	Tolerance	Weight	Tolerance
1000 g.	±0.5 g.	100 g.	±0.15 g.
900 g.	±0.45 g.	50 g.	±0.10 g.
750 g.	±0.4 g.	20 g.	±0.05 g.
500 g.	±0.35 g.	10 g.	±0.04 g.
300 g.	±0.3 g.	5 g.	±0.03 g.
250 g.	±0.25 g.	2 g.	±0.02 g.
200 g.	±0.20 g.	1 g.	±0.01 g.

The tolerances on new weights shall be one-half these values.

Glass Graduates

3. Glass graduates of 250-ml. capacities used for measuring the mixing water shall be made to deliver the indicated volume at 20 C. (68 F.). The tolerance on these graduates shall be plus or minus 2 ml. The main graduation lines of the cylinders shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around and intermediate graduations shall extend at least one fifth of the way around.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-1 on Cement.

[2] The sensibility reciprocal is a measure of the sensitivity of a balance, and is the weight required to move the position of equilibrium of the beam, pan, pointer, or other indicating device of a scale a definite amount at the capacity or at any lesser load. For a complete definition of sensibility reciprocal, see the Nat. Bur. Standards *Handbook M85*, pp. 80 to 82.

Molds

4. (*a*) Molds may be the single, double, or gang mold type that will provide 1 by 1-in. test specimens of 10-in. effective gage length. The effective gage length shall be considered as that length between the innermost points of the metal inserts used as reference points. The parts of the molds shall be tight fitting and firmly held together when assembled. The molds shall be made of hard metal not readily attacked by the cement paste. There shall be sufficient material in the sides of the molds to prevent spreading or warping.

(*b*) Each end plate of the molds shall be equipped to hold properly in place during the setting period a stainless steel or non-corroding metal reference point having a diameter of $\frac{1}{4}$-in. The reference points shall be set so that their principal axes coincide with the principal axis of the test specimen and shall extend into the specimen $\frac{5}{8}$ in.[1]

(*c*) The distance between opposite faces of the molds shall be 1 ± 0.03 in. The height of the molds, measured separately for each specimen compartment, shall be 1 ± 0.03 in. for both new molds and for molds in use. The distance between the inner ends of the reference points shall be 10 ± 0.1 in.

Autoclave

5. (*a*) The autoclave shall consist of a high-pressure steam boiler equipped with an automatic pressure control and a safety valve. The capacity of the heating unit shall be such that the pressure of the saturated steam in the autoclave may be raised in 1 to $1\frac{1}{4}$ hr. with maximum load from atmospheric to a gage pressure of 295 lb. per sq. in. (absolute pressure about 310 lb. per sq. in.). The automatic pressure control shall be capable of maintaining a pressure of 295 ± 5 lb. per sq. in. for at least 3 hr. A gage pressure of 295 ± 5 lb. per sq. in. corresponds to a temperature of 215.7 ± 1 C. (420.3 ± 2 F.).

(*b*) There shall be used in the autoclave such a quantity of water as will maintain saturated steam vapor for the entire time of test. The autoclave shall be designed to permit the pressure to drop from 295 lb. per sq. in. to less than 10 lb. per sq. in. in 1 hr. after the heat supply has been shut off.

(*c*) The autoclave shall be equipped with a vent valve for allowing the escape of air during the early part of the heating period and for releasing any steam pressure remaining at the end of the 1-hr. cooling period.

Length Comparator

6. Changes in length of the test specimens shall be measured by a dial gage or micrometer comparator having a range of at least 0.3 in. The instrument shall be graduated to 0.0001 in. and when tested at any points

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[1] The requirements in Section 4 (*a*) and (*b*) fix the length of the specimen at $11\frac{1}{4}$ in. Uniformity in equipment and procedure is essential if comparable results are to be obtained in different laboratories, and the committee, therefore, recommends adherence to the above requirements.

throughout its range the error shall not be greater than ± 0.0004 in. The difference between repeated measurements shall not be greater than 0.0001 in.

Temperature and Humidity

7. The temperature of the molding room and dry materials shall be maintained at not less than 20 C. (68 F.) and not more than 27.5 C. (81.5 F.). The temperature of the mixing water and moist closet shall not vary from 21 C. (70 F.) more than 1.7 deg. Cent. (3 deg. Fahr.). The moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 90 per cent.

Preparing Molds

8. Molds shall be thinly covered with petroleum jelly or stearic acid paste;[1] and the stainless steel or non-corroding metal reference points shall be set, care being taken to keep them clean.

Mixing Cement Paste

9. The standard batch of neat-cement paste shall consist of 800 g. of cement mixed with sufficient water to give a paste of normal consistency, in accordance with the procedure described in Sections 25 to 28 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials.[2]

Molding Test Specimens

10. Immediately following completion of mixing, two test specimens shall be molded in three equal layers, each layer being compacted with the forefinger by pressing the paste into the corners, around the reference inserts and along the surfaces of the mold. A total of 100 strokes of the forefinger shall be applied to each layer, moving from one end of the bar to the other and back two times, applying 25 strokes each trip over the length of the bar. After the top layer has been compacted, the paste shall be cut off flush with the top of the mold and the surface smoothed with a few strokes of the trowel. During the operation of mixing and placing, the hands shall be protected by rubber gloves.

Storage of Test Specimens

11. After the mold has been filled, it shall be immediately placed in a moist closet or moist room at a temperature of 21 ± 1.7 C. (70 ± 3 F.) and a relative humidity of at least 90 per cent. Specimens shall remain in the molds for at least 20 hr.; if removed from the molds before 24 hr. they shall be kept in the moist closet or moist room until tested.

Testing

12. (*a*) At 24 ± 0.5 hr. after molding, the specimens shall be removed from the moist closet one at a time, measured for length, and placed in the

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[1] Stearic acid paste is made by adding stearic acid powder to heated kerosine until a mushy consistency is obtained after cooling. When cooled, this paste shall be applied with a stiff brush.

[2] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

autoclave in a rack so that the four sides of each specimen are exposed to saturated steam in the same manner.

(*b*) The temperature of the autoclave shall be raised at such a rate as will bring the pressure of the steam from atmospheric to 295 lb. per sq. in. in 1 to $1\frac{1}{4}$ hr. To permit air to escape from the autoclave at the beginning of the test period, the vent valve shall be left open until steam begins to escape and then closed. The 295 ± 5 lb. per sq. in. pressure shall be maintained for 3 hr. At the end of the 3-hr. period at a pressure of 295 lb. per sq. in. the heat supply shall be shut off and the autoclave allowed to cool at a rate such that the pressure will gradually fall to less than 10 lb. per sq. in. in 1 hr. At the end of the 1-hr. cooling period any small pressure remaining shall be released slowly (in about 2 to 5 min.) by opening the vent valve until atmospheric pressure is attained. The autoclave shall then be opened and the test specimens immediately placed in boiling water. The water surrounding the bars shall then be slowly tempered with cool water at a rate such that the temperature of the water and specimens will be lowered to 21 C. (70 F.) in 15 min. The water surrounding the specimens shall be maintained at 21 C. (70 F.) for an additional 15 min., when the specimens shall be surface dried, and measured for length.[1]

Calculation of Autoclave Expansion

13. The difference in length of the test specimens before and after autoclaving shall be expressed as a percentage of the effective gage length and shall be reported to the nearest 0.01 per cent. The average of the expansions of the two companion test specimens shall be considered the autoclave expansion of the cement. Any test in which the percentage expansions of the individual specimens differ more than 0.05 shall be repeated.

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[1] If laboratories prefer to make all measurements at 26.5 C. (80 F.), it is recommended that upon removal of the specimens from the moist closet, they be placed in water maintained at 26.5 C. (80 F.) for at least 15 min., measured for length and then placed in the autoclave. Upon removal from the autoclave the bars and boiling water shall be cooled to 26.5 C. (80 F.) in 15 min. and kept in water at this temperature for an additional 15 min. and then measured for length.

REPORT OF SUBCOMMITTEE ON CEMENT REFERENCE LABORATORY

(Period April 1, 1937, to March 31, 1938)

Inspections were made at 153 laboratories during the period covered by this report, thus completing the field work of the fifth tour with the exception of 2 inspections for which appointments have been made. The total number of laboratories involved in this tour thus far is 309, a larger number than participated in any of the preceding tours, as shown in the following tabulation:

Classification of Laboratories	Number of Laboratories Inspected				
	Tour No. 1	Tour No. 2	Tour No. 3	Tour No. 4	Tour No. 5
Cement producers	99	108	104	100	123
Commercial testing laboratories	45	48	30	37	70
State highway laboratories[a]	25	65	53	61	64
Schools	21	27	20	13	24
Municipal	11	10	9	6	11
Miscellaneous	7	7	8	12	17
Total	208	265	224	229	309

[a] Includes highway branch laboratories, some of which are located at cement mills.

Continued interest in the work has been manifested by the U. S. Bureau of Public Roads and the Public Works Administration. For the information of their officials and other supervising offices, 94 copies of inspection reports were furnished, with the authorization of the laboratories involved.

A study was made of the percentage of acceptable apparatus encountered in this tour. As in former tours, the percentage of approved apparatus in those laboratories which had been previously inspected was in general relatively larger than for those laboratories being inspected for the first time.

A sample of cement, designated as Reference Laboratory Sample No. 2, was prepared for distribution to a large group of laboratories which have expressed a desire to cooperate in a second series of comparative tests. The sample is being sent to 173 laboratories. Many of the laboratories plan to make chemical determinations and compressive strength tests as well as the standard physical tests. It is hoped that the results of the tests may be available by the June meeting.

Work was steadily continued on the investigation being made for Committee C-1 on a group of cements containing a certain material added subsequent to calcination, these tests having been undertaken in accordance with the provisions of the Standard Specifications for High-Early-Strength Portland Cement (C 74 – 36). The work has reached the stage where tests are being made on 1-yr.-old specimens.

Study was made of some variables in testing procedure. Mr. J. R. Gran, until recently a member of the Reference Laboratory staff, published a paper[1] dealing with the differences in the assumptions made in certain methods of determining fineness.

Respectfully submitted on behalf of the subcommittee,

G. E. Warren,
Chairman.

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[1] J. R. Gran, "Some Suggested Practices in the Estimation of Particle Size Gradation of Granular Materials," ASTM Bulletin, No. 88, October, 1937, p. 17.

APPENDIX

PROPOSED REVISIONS IN STANDARDS FOR CEMENT

In this Appendix are given proposed revisions in certain standards and tentative standards for cement which are referred to earlier in this report. In connection with each title is given the reference to the publication in which the standard appears in its present form.

Revision of Tentative Standard

Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 - 34 T):[1]

Section 6.—Change from its present form: namely,

6. The sieving apparatus, consisting of a No. 325 sieve, 2 in. in diameter and having side walls 3 in. in height, shall conform to the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials. A spray nozzle having seventeen 0.02-in. holes in the tip shall be used for washing the sample through the sieve. A pressure gage shall be installed in the water line between the shut-off valve and the nozzle so that the pressure on the nozzle can be regulated.

to read as follows:

6. The sieve shall be 2 in. in diameter and have side walls 3 in. in height, and shall be fitted with a No. 325 wire screen cloth, which cloth shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, and be such that the sieving correction obtained shall not be greater than 15 per cent (see Section 10 (*b*)).

Section 7.—Change from its present form: namely,

7. The stirring apparatus shall consist of a brush, which will fit the contour of the bottom of a test tube, attached to a stirring motor. The brush shall rotate at a speed of approximately 500 r.p.m.

to read as follows:

7. The stirring apparatus shall consist of either (*a*) a cylindrical brush, $\frac{3}{4}$ in. in diameter and about $1\frac{3}{4}$ in. in length, with an end approximately fitting the contour of the bottom of a $\frac{7}{8}$-in. diameter test tube, or (*b*) any other stirring device which will be equally efficient in dispersion as measured by specific surface determinations on a standard sample. The stirring apparatus shall rotate at a speed of approximately 3500 r.p.m.

Section 10 (b).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

(*b*) Calibration of the No. 325 Sieve.—The spray nozzle and pressure gage shall be connected to a water supply line and the pressure on the spray nozzle adjusted to 10 lb. per sq. in. One gram of National Bureau of Standards' Standard Sample No. 114 shall be placed in the No. 325 sieve and washed [through the sieve] for 1 min. The sieve and residue shall be dried in an oven or over a hot plate (Note 1) and the residue brushed from the sieve *and* weighed on an analytical balance [and the percentage passing calculated] (*Note 2*). The difference between the [value] *amount of residue* obtained in this manner, and the [value] *amount of residue indicated by the fineness* specified for the standard sample, *expressed as a percentage of the latter residue*, shall be the sieve correction (Note [2] *3*).

Add a new note, designated Note 3, to read as follows:

Note 3.—It should be observed that the sieve correction as specified is a *factor to be multiplied* by the residue obtained and that the amount to be added or subtracted from the residue in any given test is therefore proportional to the amount of residue.

Section 11.—Change from its present form: namely,

11. A 0.3-g. sample of the cement to be tested shall be used for a very fine cement (more than 85 per cent passing a No. 325 sieve), 0.4 g. for a medium cement (70 to 85 per cent passing a No. 325 sieve), and 0.5 g. for a coarse cement (less than 70 per cent passing a No. 325 sieve) (Note).

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 777 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 466.

NOTE.—The size of sample is selected so that the microammeter readings will fall in the middle portion of the microammeter scale.

to read as follows:

11. The size of the sample of cement shall be so selected that the microammeter readings will fall in the middle portion of the microammeter scale (Note).

NOTE.—The following approximations will be helpful in many instances in selecting the size of sample; 0.3-g. sample for a cement of which more than 85 per cent passes a No. 325 sieve; 0.4-g. sample for a cement of which 70 to 85 per cent passes a No. 325 sieve; 0.5-g. sample for a cement of which less than 70 per cent passes a No. 325 sieve.

Section 13.—Change the first two sentences of Paragraph (*a*) to read as follows by the addition of the italicized words:

13. (*a*) The cement sample shall be placed in a test tube with 10 to 15 ml. of kerosine and 5 drops of oleic acid (*U.S.P.*). (Oleic acid is added as a dispersing agent and has slight or no effect on the viscosity of the kerosine. *The oleic acid should be kept in a well-stoppered dark-glass bottle.*)

Change the second sentence of Paragraph (*b*) to read as follows by the addition of the italicized words and the omission of those in brackets:

The tank shall be covered with a ground-glass cover and oscillated 180 deg. about a horizontal axis [at the rate of approximately one inversion per] *turning the tank upside down and back again to its original upright position once each* second for one minute (Note 1).

Section 14 (e).—Change to read as follows by the addition of the italicized word:

(*e*) The retarding filter shall be *immediately* removed from the light path and the cabinet door closed.

Revisions of Standards, Immediate Adoption

Standard Specifications for Portland Cement (C 9 - 37):[1]

Section 1.—Omit this section covering the definition of portland cement, which reads as follows, renumbering the subsequent sections accordingly:

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

Section 2.—Following the table in this section (redesignated Section 1), add a new paragraph and note to read as follows:

Portland cement is the product obtained by pulverizing clinker consisting essentially of calcium silicates, to which no additions have been made subsequent to calcination other than water and/or untreated calcium sulfate except that additions not to exceed 1 per cent of other materials may be added, provided such materials have been shown not to be harmful by tests prescribed and carried out by Committee C-1 on Cement.

NOTE.—Tests to determine whether a proposed addition is harmful will be carried out by Committee C-1 on Cement, for those making requests, through its Cement Reference Laboratory or other laboratory which the committee may select. As such tests are completed the committee will make known those additions which have been found not to be harmful. (For details regarding the conditions under which the tests will be made, address Technical Assistant, Committee C-1, Cement Reference Laboratory, National Bureau of Standards, Washington, D. C.)

Standard Specifications for High-Early-Strength Portland Cement (C 74 - 36):[2]

Section 2.—Omit this section covering the fineness requirement which reads as follows, renumbering the subsequent sections accordingly:

2. The specific surface shall not be less than 1900 sq. cm. per gram of cement.

Section 10.—Omit Paragraph (*a*) which reads as follows:

(*a*) *Fineness.*—The specific surface shall be determined in accordance with the Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (A.S.T.M. Designation: C 115 – 34 T) of the American Society for Testing Materials.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 49.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 4.

REPORT OF COMMITTEE C-7
ON
LIME

Committee C-7 on Lime has held four regular meetings and one special meeting since the presentation of its report in 1936, as follows: on July 3, 1936, in Atlantic City, N. J., on January 12, 1937, in Washington, D. C. (Special), on March 4, 1937, in Chicago, Ill., on June 29, 1937, in New York, N. Y., and on March 17, 1938, in Pittsburgh, Pa.

Personnel changes in the committee include the addition of eight new members, the resignation of three and the death of one member. Several changes have been made in the representatives of corporate members. The membership of the committee now totals 43, classified as 23 producers, 6 consumers, and 14 general interest members. The numeric preponderance of the producer element resulted from the recent loss of three consumer and general interest members. The committee recognizes this situation and intends to adjust it as soon as possible.

RECOMMENDATIONS AFFECTING STANDARDS

Proposed Revision of Tentative Standard:

The committee recommends the deletion of the soundness test as described in Sections 4 and 5 of the Tentative Methods of Physical Test for Limestone, Quicklime and Hydrated Lime (C 110 – 34 T).[1] Continued study of the soundness test has convinced the committee that it is an unsatisfactory method for the following reasons:

1. It is an accelerated test which in no way simulates the use of the materials in field practice and at the same time it disqualifies certain types of lime long used successfully for construction purposes.

2. It has been found that the test does not consistently yield clear-cut indications of soundness or unsoundness, partly because of the difficulty in preparing concise directions relative to interpretation of results.

3. There is no value in retaining a proposed test which produces laboratory results at variance with field experience, particularly when there exists a standard constancy of volume test (Section 11 of the Standard Specifications for Hydrated Lime for Structural Purposes (C 6 – 31))[2] which adequately protects the consumer.

Data supporting these points are on record in the committee's files. The most convincing proof of the unreliability of the test is demonstrated by the fact that samples of lime plaster in "sound" condition taken from old buildings in several leading cities tested "unsound" by the accelerated autoclave method.

During the coming year the committee plans to continue its investigation of methods for determining the soundness of limes, the results of which will be submitted as a progress report at the next annual meeting of the Society.

The Tentative Specifications for Quicklime for Structural Purposes (C 5 - 34 T), and for Hydrated Lime for Structural Purposes (C 6 – 34 T), have been tentative for more than three years without revision. The committee recommends that they be continued as tentative pending Society action relative to the autoclave test recommendation as mentioned earlier in this report.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 754 (1934); also 1937 Book of A.S.T.M. Tentative Standards, p. 484.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 30

ACTIVITIES OF SUBCOMMITTEES

Committee C-7 approved the suggestion of Subcommittee III on Lime for the Chemical Industries (D. E. Washburn, chairman) that the following proposed specifications and methods be published as information as appendices to this report for the purpose of obtaining constructive suggestions from members of the Society before recommending them for acceptance as tentative standards:

Proposed Specifications for Quicklime for Causticizing Leached Liquors in the Soda-Pulp Process for the Manufacture of Paper,

Proposed Specifications for Quicklime for Use in the Manufacture of Paper Pulp where the Precipitated Carbonate is Employed as a Pigment or Filler, and

Proposed Method for Determination of Available Lime in High-Calcium Quicklime and Hydrated Lime by the Rapid Sugar Test.

The above accordingly appear as Appendices I, II and III to this report.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 43 members; the results being shown in Table I.

The election of officers resulted in the selection of the following members to serve during the ensuing term of two years:

Chairman, James R. Withrow.
Vice-Chairman, E. E. Eakins.
Vice-Chairman, L. S. Wells.
Secretary, J. W. Stockett, Jr.

This report has been submitted to letter ballot of the committee, which consists of 43 members; 35 members returned their ballots, of whom 28 have voted affirmatively and 1 negatively.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. REVISION OF TENTATIVE STANDARD			
Methods of Physical Test for Limestone, Quicklime and Hydrated Lime (C 110 – 34 T)[a]	29	6	2
II. PROPOSED SPECIFICATIONS AND METHODS FOR PUBLICATION AS INFORMATION ONLY			
Proposed Specifications for Quicklime for Causticizing Leached Liquors in the Soda-Pulp Process for the Manufacture of Paper	27	0	8
Proposed Specifications for Quicklime for Use in the Manufacture of Paper Pulp where the Precipitated Carbonate is Employed as a Pigment or Filler	28	0	7
Proposed Method for Determination of Available Lime in High-Calcium Quicklime and Hydrated Lime by the Rapid Sugar Test	28	1	6

[a] The classified vote on the revision of the Tentative Methods of Test for Limestone, Quicklime and Hydrated Lime (C 110 - 34 T) is as follows: Affirmative: 18 producers, 1 consumer, 10 general interests; negative: 2 producers, 1 consumer, 3 general interests; "not voting:" 1 producer, 1 consumer.

Respectfully submitted on behalf of the committee,

JAMES R. WITHROW,
Chairman.

W. V. BRUMBAUGH,
Acting Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee C-7 on Lime presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Specifications for Hydraulic Hydrated Lime for Structural Purposes, and

Proposed Tentative Revision of Standard Definitions of Terms Relating to Lime (C 51 – 28).

These recommendations were accepted by Committee E-10 and appear on pp. 757 and 1325, respectively.

APPENDIX I

PROPOSED SPECIFICATIONS
FOR
QUICKLIME FOR CAUSTICIZING LEACHED LIQUORS IN THE SODA-PULP PROCESS FOR THE MANUFACTURE OF PAPER[1]

These are **proposed specifications** and are published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

> In the manufacture of pulp by the soda process, the wood is cooked with a caustic soda solution which dissolves the non-celluloses of the wood substance and is obtained as black liquor after washing the pulp. This is evaporated and burned in rotary furnaces or spray-type furnaces, the resultant product being sodium carbonate which is leached from the black ash if the rotary-type furnace is used, or as a solution of sodium carbonate from the molten soda ash which is discharged from the hearth of the spray-type furnace. Lime is used to reconvert the sodium carbonate into caustic soda. Bulk quicklime is generally used. High-calcium limes are usually preferable, as very appreciable quantities of magnesia generally produce slow settling sludges.

1. (*a*) *Requirements.*—The quicklime shall contain 90 per cent available lime, calculated on the basis of the weight taken at the point of manufacture.

(*b*) The calcium carbonate produced by the interaction of the lime and sodium carbonate shall settle rapidly enough so that the liquor can be decanted and the sludge washed by decantation in a reasonable length of time.

2. *Methods of Test.*—The chemical analysis for available lime shall be made in accordance with the Standard Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (A.S.T.M. Designation: C 25) of the American Society for Testing Materials.[2]

3. *Sampling, Inspection, Rejection.*—The sampling, inspection, rejection, retesting, packing and marking shall be conducted in accordance with the Standard Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products (A.S.T.M. Designation: C 50) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, these proposed specifications are under the jurisdiction of the A.S.T.M. Committee C-7 on Lime.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 51.

[3] *Ibid.*, p. 68.

APPENDIX II

PROPOSED SPECIFICATIONS
FOR
QUICKLIME FOR USE IN THE MANUFACTURE OF PAPER PULP WHERE THE PRECIPITATED CARBONATE IS EMPLOYED AS A PIGMENT OR FILLER[1]

These are **proposed specifications** and are published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Physical properties such as color and fineness are of prime importance in a pigment or filler. As the chemical composition of the quicklime bears no direct relation to these properties, either high-calcium or dolomitic quicklimes can be employed. With high-calcium limes, usually the soft-burned type is preferable. Dolomitic limes, owing to the magnesia being inactive in causticizing soda ash, usually yield a finer precipitate.

In practice, the lime is slaked in water or weak sodium carbonate liquor and boiled in suitable proportions so that a causticity of at least 90 per cent is obtained. Sometimes a double boiling process is used. In the first boil an excess of lime is used so that a high causticity liquor is secured, the lime sludge filtered off, and reboiled with excess sodium carbonate to carbonate the excess lime. The precipitate is then screened to remove grit and washed with water to remove soluble sodium compounds. The lime is evaluated according to the fineness and whiteness of the resultant carbonate precipitate.

Causticity is determined according to the tentative standard method T-613-m of the Technical Association of the Pulp and Paper Industry, as follows:

Pipette 50 ml. of the original solution into a 500-ml. beaker, dilute to about 400 to 450 ml. with freshly boiled and cooled water, add 1 ml. of phenolphthalein solution and with the tip of the burette beneath the surface of the solution, titrate with 0.5 N acid until the pink color just disappears. Then add three or four drops of methyl orange indicator and continue the titration to the first appearance of a permanent pink color. The first titration gives the number of milliliters of acid required to neutralize all the hydroxide and half of the carbonate, since phenolphthalein is neutral to bicarbonate. The total titration with both indicators gives the total alkalinity. The calculations are as follows:

Milliliters of acid due to carbonate $= 2(B - A)$

Milliliters of acid due to hydroxide $= B - 2(B - A) = 2A - B$

where A = the milliliters of acid required with phenolphthalein, and
B = the milliliters of acid required with methyl orange (total titration).

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[1] Under the standardization procedure of the Society, these proposed specifications are under the jurisdiction of the A.S.T.M. Committee C-7 on Lime.

1. (*a*) *Requirements.*—Bulk quicklime is generally used.

(*b*) For use as a filler in paper, the settling rate of the carbonate precipitate should show 100 to 150 ml. of clear liquor after the first 5 min., according to the method of test specified in Section 2.

(*c*) For use as a paper coating, this settling rate should show less than 100 ml. of clear liquor after the first 5 min. of settling according to the method of test specified in Section 2.

2. *Method of Test.*—In a 1500-ml. beaker or metal container, slake 60 g. of lime in enough water at 180 F. (82 C.) to make a creamy hydrate. Dissolve 100 g. of Na_2CO_3 in water, heat to 180 F. (82 C.), stir into lime paste, and add enough water at or above this temperature to make 700 ml. Boil for 1 hr., making up loss for evaporation at 15-min. intervals.

Collect precipitate on a Büchner funnel, wash free of NaOH and determine settling rate by using the equivalent of 50 g. bone-dry precipitate in 1000 ml. of water in a liter graduate. Use cylinder approximately 2⅜ in. in diameter (which is a common size for commercial cylinders of this capacity). Agitate thoroughly (by inverting cylinder ten times), let settle, and then take reading of clear supernatant liquor after intervals of 5, 15, 30 min. and compaction point (point of maximum settling, usually constant after 24 hr.).

APPENDIX III

PROPOSED METHOD FOR DETERMINATION OF AVAILABLE LIME IN HIGH-CALCIUM QUICKLIME AND HYDRATED LIME BY THE RAPID SUGAR TEST[1]

This is a **proposed method** and is published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

1. *Hydrochloric Acid Solution.*—Make a solution consisting of 13.7 ml. of HCl (sp. gr. 1.19) per liter. This usually gives a solution slightly stronger than necessary. Standardize the HCl solution[2] against 0.85 g. of pure dry sodium carbonate using methyl orange as an indicator. Adjust this solution either by the addition of water if too strong, or HCl if too weak, so that the 0.85 g. Na_2CO_3 requires exactly 90 ml. of HCl.

2. *Procedure.*—Weigh out 0.5 g. of the prepared sample (passing a No. 100 sieve) and brush carefully into a 350-ml. Erlenmeyer flask, containing from 10 to 20 ml. of distilled water, and immediately stopper the flask with a rubber stopper (Note 1). Be sure that the sample is thoroughly dispersed in the water by giving the flask a slight swirling motion. Allow it to stand 5 min. Remove stopper and add 15 g. of granulated sugar (sucrose) and then 150 ml. of distilled water (room temperature) on top of the sugar (Note 2). Stopper the flask and shake vigorously at intervals for a 5-min. period, and allow to stand for 30 min., but not longer than 1 hr. Add two drops of phenolphthalein indicator, wash down the stopper and sides of flask with distilled water (Note 3). Titrate (in the original flask) with HCl standardized to such strength (Section 1) that 1 ml. is equivalent to 1 per cent CaO.

NOTE 1.—It is particularly important to have a little water in the flask before adding the sample. This is especially true in the case of quicklime because frequently by adding water on top of a dry charge in a flask there is a tendency for the material to cake and form lumps difficult to completely dissolve in the sugar solution later. On the other hand, if the lime is added to a little water, conditions are favorable to a thorough dispersion of fine particles to produce a more rapid solution. In the case of quicklime, probably some slaking action occurs to facilitate the dispersion and solution.

NOTE 2.—The 15 g. of sugar and the 150 ml. of water used are only approximate amounts. It is not necessary to weigh the sugar each time. A small measure can be employed, such as a spoon which when level full holds slightly more than 15 g. This saves time in running a large number of samples, and gives just as accurate results as when the sugar is carefully weighed. A little excess weight of sugar always insures at least a 10 per cent sugar solution.

NOTE 3.—In titrating, first add about 90 per cent of the acid requirement from a 100-ml. burette without shaking. Then shake the flask and finish the titration more carefully, but as rapidly as possible (shaking the flask vigorously), to the first complete disappearance of pink color. Note the reading in per cent and ignore return of color. Unless the operator is familiar with previous analyses of the lime under test, and in cases where the available lime content varies to extremes, it is good practice to run a preliminary test by slow titration to determine the proper amount to add without first shaking the flask. Inasmuch as the method is very simple, this entails no great hardship.

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[1] Under the standardization procedure of the Society, this proposed method is under the jurisdiction of the A.S.T.M. Committee C-7 on Lime.

[2] Also check the HCl against the Standard Sample 48*a* for benzoic acid of the National Bureau of Standards through a sodium hydroxide solution.

REPORT OF COMMITTEE C-8
ON
REFRACTORIES

Committee C-8 on Refractories held two meetings during the year: in Bedford Springs, Pa., on September 2, 1937, and in New Orleans, La., on March 28, 1938. The former was held in conjunction with the summer meeting of the Refractories Division of the American Ceramic Society and the latter in conjunction with the annual meeting of that society.

The committee has been active during the year and has in progress the development of a large number of test methods to be used by the industry.

The only change in the organization of subcommittees was the appointment of a new section, under Subcommittee III on Tests, entitled "Section on Porosity and Permanent Volume Change" (C. E. Fulton, chairman).

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

The committee is presenting for publication as tentative, as appended hereto,[1] the following two new test methods for the reasons indicated below:

- Tentative Methods of Test for Size, Warpage, and Bulk Specific Gravity of Refractory Brick, in order to satisfy a need in the industry for a uniform method of testing, and
- Tentative Method of Test for True Specific Gravity of Burned Refractory Materials, in order to establish a uniform procedure in different laboratories for determining and reporting true specific gravity.

Tentative Revisions of Standards:

The committee recommends for publication as tentative, revisions of five standards, as follows:

Standard Specifications for Fireclay Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 – 36),[2] *for Fireclay Brick for Stationary Boiler Service (C 64 – 36),*[2] *and for Marine Boiler Service (C 65 – 28).*[2]—Since these specifications at present do not provide for permissible variations in warpage, the following revision is recommended:

Section 2.—Change this section covering permissible variations in size from its present form: namely,

> 2. Variations of ±2 per cent from specified dimensions covering both shrinkage and warpage shall be allowed on dimensions of 4 in. or over. On dimensions under 4 in., variations of ±3 per cent shall be allowed. These permissible variations apply in general throughout these specifications.

to read as follows:

> 2. (*a*) Fireclay brick shall conform to specified dimensions as to size within the following permissible variations:
>
> | DIMENSION | PERMISSIBLE VARIATION |
> |---|---|
> | 4 in. or over | ±2 per cent |
> | Under 4 in | ±3 per cent |
>
> (*b*) The permissible variations in size specified in Paragraph (*a*) shall apply in general throughout these specifications.

New Section.—Add a new section, designated Section 3 covering permissible variations in warpage, to read as follows, renumbering the subsequent sections accordingly:

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[1] See pp. 791 and 793.

[2] 1936 Book of A.S.T.M. Standards, Part II, pp. 189, 194, 200.

3. Ninety-five per cent of the shapes shall not show a warpage greater than $\frac{1}{8}$ in. per linear ft. of the diagonal used in making the measurement.

Standard Specifications for Refractories for the Construction of Incinerators (C 106 - 36).[1]

Make the same change in Section 3 of these specifications as is recommended above in Specifications C 63, C 64, and C 65.

Standard Definitions for Fireclay Refractories (C 27 - 37).[2]—Although Standard Specifications C 63, C 64, and C 65 define fireclay brick as being of siliceous grade when the silica content is greater than 65 per cent and non-siliceous when the silica content is 65 per cent or less, the Standard Definitions C 27 define siliceous fireclay brick as those with a silica content of 70 per cent or over. In order to make the definitions conform to the specifications, the committee is recommending the following revision:

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Methods of Test for Size, Warpage, and Bulk Specific Gravity of Refractory Brick	23	0	1
Method of Test for True Specific Gravity of Burned Refractory Materials	24	0	0
II. TENTATIVE REVISIONS OF STANDARDS			
Specifications for Fireclay Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 - 36)	23	0	1
Specifications for Fireclay Brick for Stationary Boiler Service (C 64 - 36)	23	0	1
Specifications for Fireclay Brick for Marine Boiler Service (C 65 - 28)	23	0	1
Specifications for Refractories for the Construction of Incinerators (C 106 - 36)	23	0	1
Definitions for Fireclay Refractories (C 27 - 37)	27	1	1
III. EDITORIAL REVISION OF TENTATIVE STANDARD			
Methods of Chemical Analysis of Refractory Materials (C 18 - 37 T):			
Change in Preface	27	0	2
Change in Sections 9 and 31	28	0	1

Under the center heading preceding Section 4, change the parenthetical subheading to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

(Silica content less than [70] *65* per cent.)

Under the center heading preceding Section 6, change the parenthetical subheading to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

(Silica content [70] *65* per cent or over.)

Editorial Revision of Tentative Standard:

Tentative Methods of Chemical Analysis of Refractory Materials (C 18 - 37 T).[3]—The committee, on advice of interested parties, believes that the use of potassium dichromate as well as potassium permanganate should be permitted in the determination of iron oxide in refractory materials, and that the use of an evaporating dish made of porcelain is not essential for evaporation. It is therefore recommended that the following editorial changes be made in these methods:

Preface.—Change the fifth sentence to read as follows by the addition of the italicized words:

> The other procedures commonly in use include reduction of an oxidized solution with zinc, or other metal, and titration with standard $KMnO_4$ or $K_2Cr_2O_7$ *as well as* titration with a standard solution of titanous chloride in an oxidized solution.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 204.

[2] 1937 Supplement to Book of A.S.T.M. Standards, Part II, p. 85.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 760 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 534.

Section 9.—Change the ninth sentence to read as follows by the omission of the word in brackets:

> Transfer the contents of the beaker to an [porcelain] evaporating dish and evaporate to dryness on a steam bath.

Section 31.—Change the fifth sentence to read as follows by the omission of the word in brackets:

> Dissolve the melt in diluted HCl (1:4) in an [porcelain] evaporating dish, add 2 to 3 ml. of diluted H_2SO_4 (1:1) (Note 1) and evaporate to dryness.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 32 members, the results being shown in Table I.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Industrial Survey (L. C. Hewitt, chairman).—The Manual of A.S.T.M. Standards on Refractory Materials, published in November, 1937, contained an industrial survey, prepared by this subcommittee, entitled "Industrial Survey of Conditions Surrounding Refractory Service in the Glass Industry as it Pertains to Continuous Bottle Furnaces." The subcommittee has just completed an industrial survey of refractory service in the lime industry which it is proposed to include with other surveys in the C-8 Manual.

Subcommittee II on Research (F. A. Harvey, chairman).—This subcommittee has been active in conducting an investigation on methods of testing insulating refractories, and in studying additional refinements of the panel spalling test. Most of the work of the subcommittee is carried on in conjunction with that of Subcommittee III on Tests.

Subcommittee II is presenting for publication a proposed Tentative Method of Test for True Specific Gravity of Burned Refractory Materials, as appended hereto.[1]

Subcommittee III on Tests (F. A. Harvey, chairman):

Section A on Load (C. M. Dodd, chairman) is working on designs for load test furnaces involving direct loading as an alternative to the beam loading prescribed in the Standard Method of Test for Refractory Materials Under Load at High Temperatures (C 16 – 36).

Section B on Spalling (R E. Birch, chairman) has been carrying on work on the panel spalling test to develop means of avoiding the occasional occurrence of more spalling in the center of the panel than occurs at the outer edges, to devise a better way of specifying back-up insulation, and of lessening the human element in spall removal. The section presented a comprehensive report on this subject which has been submitted to the members of Committee C-8 for study and comment before the present standard methods of panel spalling test are revised.

Section C on Temperature (R. B. Sosman, chairman) presented a comprehensive report on P.C.E. furnaces now in use in this country, and on fundamental concepts of heating by fuel and by electricity. It is believed that the fundamental studies being made by this section will result in the development of a generally acceptable P.C.E. furnace.

Section E on Analysis (L. J. Trostel, chairman) is working on a revision of that portion of the Tentative Methods of Chemical Analysis of Refractory Materials (C 18 – 37 T) covering procedures for chrome ores and chrome brick.

Section F on Tests on Refractory Insulation (W. C. Rueckel, chairman) has been working on the development of test methods for insulating block and refractories. It is believed that in a short time satisfactory procedures can be recommended.

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[1] See p 793.

Section G on Porosity and Permanent Volume Change (C. E. Fulton, chairman) was organized during the past year to study the Standard Method of Test for Porosity and Permanent Volume Changes in Refractory Materials (C 20 - 33) to ascertain if it is still in accord with present practice.

Subcommittee IV on Heat Transfer (R. H. Heilman, chairman).—This subcommittee is continuing the cooperative work with the National Bureau of Standards on the method of determining thermal conductivity of refractory materials at high temperatures. The subcommittee also is initiating a study of methods of determining thermal conductivity of block insulation. In the 1937 edition of the C-8 Manual the subcommittee presented a Recommended Procedure for Calculating Heat Losses Through Furnace Walls.

Subcommittee V on Precision and Tolerance (R. A. Heindl, chairman).—This subcommittee is obtaining data from various sources on the size of samples necessary for proper representation of the original material in the final sample used for testing.

Subcommittee VII on Specifications (G. A. Bole, chairman).—This subcommittee is submitting for publication a proposed Tentative Method of Test for Size, Warpage, and Bulk Specific Gravity of Refractory Brick, as appended hereto.[1]

Subcommittee VIII, Editorial (L. J. Trostel, chairman).—This subcommittee was active in the preparation of material included in the Manual of A.S.T.M. Standards on Refractory Materials which was published in November, 1937.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 32 members; 26 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. D. SULLIVAN,
Chairman.
E. H. VAN SCHOICK,
Vice-Chairman.

S. M. PHELPS,
Secretary.

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[1] See p. 791.

REPORT OF COMMITTEE C-9 ON CONCRETE AND CONCRETE AGGREGATES

Committee C-9 on Concrete and Concrete Aggregates held three meetings during the year, two of which were held in Washington, D. C., on December 4, 1937, and on March 31, 1938, and one during the annual meeting of the Society in Atlantic City, N. J.

The year's work has resulted in recommendations for three new tentative methods of test, and the adoption as standard of two tentative methods and of tentative revisions in two standards. In addition, the following papers are being presented in Appendices I and II, respectively, to this report:

"Stress-Strain Characteristics of Mortars and Concretes," by H. J. Gilkey and Glenn Murphy, submitted by Subcommittee VI on Relation of Characteristics of Materials and Mixtures to Properties of Concrete, and

"Factors Affecting the Testing of Concrete Aggregate Durability," by Charles E. Wuerpel, submitted by Subcommittee XVII on Conditions Affecting Durability of Concrete in Structures.

On the recommendation of Subcommittee IX on Specifications and Methods of Tests of Aggregates (H. F. Clemmer, chairman) the committee is presenting the following proposed methods as information only. It is expected that these proposals will be acted on at the annual meeting for presentation to the Society during the summer through Committee E-10 on Standards:[1]

Proposed Method of Test for Clay Lumps in Aggregate, as appended hereto;[2]

Proposed Revision of Tentative Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131 – 37 T), as appended hereto.[3] This method is under the joint jurisdiction of Committee C-9 and Committee D-4 on Road and Paving Materials, and an explanation of the changes proposed is given in the current report of Committee D-4.[4]

Proposed Tentative Revision of Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27), as appended hereto,[5] and

Proposed Tentative Revision of Standard Method of Test for Structural Strength of Fine Aggregate Using Constant Water-Cement-Ratio Mortar (C 87 – 36),[6] revised as follows:

Section 2.—Change the third sentence from its present form: namely,

> Saturated and surface-dried sand from a sample of known weight[a] shall be beaten into the mixture until the material appears to be of the desired consistency (flow 100 ± 5).
>
> [a] For six 2-in. cubes, 600 g. of cement and 359 cc. of water will usually give sufficient mortar. The quantity of sand used with this amount of cement may vary from 1200 g. for fine sand to 2000 g. or more for coarse sand.

to read as follows:

> A sample of sand of known weight,[a] which has been placed in a saturated surface-dry
>
> [a] For six 2-in. cubes, 600 g. of cement and 360 ml. of water will usually give sufficient mortar. The quantity of sand used with this amount of cement may vary from 1200 g. for fine sand to 2000 g. or more for coarse sand.

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[1] See Editorial Note, p. 316.

[2] See p. 806.

[3] See p. 803.

[4] See p. 817.

[5] See p. 1325.

[6] 1936 Book of A.S.T.M. Standards, Part II, p. 355.

condition[b] by means of the procedure specified in Section 3 of the Tentative Method of Test for Specific Gravity and Absorption of Fine Aggregate (A.S.T.M. Designation: C 128 - 36 T) of the American Society for Testing Materials, shall be beaten into the mixture until the material appears to be of the desired consistency (flow 100 ± 5).

[b] If the absorption as determined by the Tentative Method of Test for Specific Gravity and Absorption of Fine Aggregate (A.S.T.M. Designation: C 128 - 36 T) of the American Society for Testing Materials is known, sand may be prepared for test by adding to a known weight of dry sand the amount of water it will absorb, and permitting the sand to stand in a covered pan for 30 min. before use.

Section 3.—After the first sentence add three new sentences to read as follows:

The flow table with the attached shaft shall weigh 9 ± 1 lb. The frame of the table shall be attached rigidly to a concrete pedestal which in turn is attached rigidly to the floor. The concrete pedestal shall be at least 8 in. in diameter and 25 in. in height and shall weigh at least 100 lb.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

The committee submits for publication as tentative the following new methods of test, as appended hereto:[1]

Tentative Methods of:

Test for Determination of Yield of Concrete, prepared for the purpose of standardizing a procedure in a field where several different procedures are being used;

Test for Soundness of Aggregates by Freezing and Thawing, prepared to encourage investigation of one of the very important factors involved in durability of concrete; it fulfills a very marked need in testing procedure; and

Test for Sieve Analysis of Fine and Coarse Aggregates, prepared in cooperation with Committee D-4 on Road and Paving Materials for the purpose of drafting a single method of test to replace four existing standard methods which are accordingly recommended to be withdrawn, as indicated below.

Adoption of Tentative Standards as Standard:

The committee recommends that the following tentative methods of test which have been in satisfactory use be approved for reference to letter ballot of the Society for adoption as standard:

Tentative Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Third Point Loading (C 78 - 36 T),[2] and

Tentative Method of Test for Flow of Portland-Cement Concrete by Use of the Flow Table (C 124 - 36 T).[2]

Adoption as Standard of Tentative Revisions of Standards:

The committee recommends that the tentative revisions in the following four standards which were submitted for publication as tentative last year[3] be approved for reference to letter ballot of the Society for adoption as standard:

Standard Method of Making and Storing Compression Test Specimens of Concrete in the Field (C 31 - 33),[4]

Standard Specifications for Ready Mixed Concrete (C 94 - 35),[4]

Standard Specifications for Curing Portland-Cement Concrete Slabs with Calcium Chloride Admixture (C 82 - 34),[4] and

Standard Specifications for Curing Portland-Cement Concrete Slabs by Surface Application of Calcium Chloride (C 83 - 36).[4]

Withdrawal of Standards:

The committee recommends the withdrawal of the following four test methods inasmuch as they are being replaced by the new Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates, as mentioned above:

Standard Methods of:

Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 18 - 16),[5]

Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 19 - 16),[5]

Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete (D 7 - 27),[5] and

Test for Sieve Analysis of Aggregates for Concrete (C 41 - 36).[5]

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[1] See pp. 819, 811, and 808.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, pp. 796, 803 (1936); also 1937 Book of A.S.T.M. Tentative Standards, pp. 595, 602.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1315, 1313, 1312 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1573, 1571, 1570.

[4] 1936 Book of A.S.T.M. Standards, Part II, pp. 337, 313, 326, 327.

[5] *Ibid.*, pp. 1075, 1076, 1077, 353.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 61 members, 44 members returned their ballots, the results being given in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirm-ative	Neg-ative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Method of Test for Determination of Yield of Concrete	43	1	0
Method of Test for Soundness of Aggregates by Freezing and Thawing	40	2	2
Method of Test for Sieve Analysis of Fine and Coarse Aggregates	43	0	1
II. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Third Point Loading (C 78 - 36 T)	41	0	3
Method of Test for Flow of Portland-Cement Concrete by Use of the Flow Table (C 124 - 36 T)	41	0	3
III. ADOPTION AS STANDARD OF TENTATIVE REVISIONS OF STANDARDS			
Method of Making and Storing Compression Test Specimens of Concrete in the Field (C 31 - 33)	44	0	0
Specifications for Ready Mixed Concrete (C 94 - 35)	41	0	3
Specifications for Curing Portland-Cement Concrete Slabs with Calcium Chloride Admixture (C 82 - 34)	28	1	8
Specifications for Curing Portland-Cement Concrete Slabs by Surface Application of Calcium Chloride (C 83 - 36)	28	1	8
IV. WITHDRAWAL OF STANDARDS			
Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 18 - 16)	42	0	2
Method of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 19 - 16)	42	0	2
Method of Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete (D 7 - 27)	42	0	2
Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 - 36)	43	0	1

The election of officers for the ensuing term of two years resulted as follows:

Chairman, F. H. Jackson
Vice-Chairman, F. E. Richart
Secretary, R. R. Litehiser
Chairman of Finance Committee, H. J. Love

Members-at-Large of Executive Committee	H. F. Clemmer R. W. Crum H. J. Gilkey A. T. Goldbeck J. C. Pearson C. H. Scholer Stanton Walker M. O. Withey

Dr. A. N. Talbot continues as honorary chairman, to which he was unanimously elected two years ago.

This report has been submitted to letter ballot of the committee which consists of 61 members; 44 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. W. CRUM,
Chairman.

R. R. LITEHISER,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee C-9 on Concrete and Concrete Aggregates presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Method of Test for Clay Lumps in Aggregates, Proposed Revision of Tentative Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131 – 37 T), recommended jointly with Committee D-4 on Road and Paving Materials,

Proposed Tentative Revision of Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27) in the form of new Tentative Method of Test for Unit Weight of Aggregate, and

Proposed Tentative Revision of Standard Method of Test for Structural Strength of Fine Aggregate Using Constant-Water-Cement-Ratio Mortar (C 87 – 36).

These recommendations were accepted by Committee E-10 and appear on pp. 806, 803, 817, and 1325, respectively.

APPENDIX I

STRESS-STRAIN CHARACTERISTICS OF MORTARS AND CONCRETES

By H. J. Gilkey[1] and Glenn Murphy[1]

For concrete, as for most other engineering materials, research curiosity has necessarily been directed toward the determination and cataloging of those properties which were recognized as having the greatest influence upon suitability for current uses. The property first so recognized was strength, which continues to be considered important, sometimes in its own right, but now more often, perhaps, as an index to such other desired qualities as durability or impermeability. Because of its use in the mechanics of reinforced concrete design, the elastic stiffness, as measured by Young's modulus (modulus of elasticity, so called), was another property about which early interest centered. More recently many other properties and characteristics have come actively into the picture because of recognition that they, too, bear upon the suitability of concrete in its many adaptations.

At present engineers recognize as important not only the properties of compressive strength, elastic strength (usually measured by the proportional limit), elastic stiffness (Young's modulus), and Poisson's ratio, all of which measure the behavior of concrete under slowly applied short-time loading, but also such qualities as plastic flow under sustained loading, volume change from moisture and temperature variations, resistance to impact and repeated loading, impermeability to water and to water vapor, and durability in all its varied manifestations. For concrete in process of fabrication or hardening, other factors are recognized as important, among which are: workability or placeability, time of set, rate of hardening, shrinkage, and heat generation.

Much chemical research has contributed greatly toward an understanding of the basic hardening processes, but of the physical phenomena of resistance to breakdown there are but few recorded efforts[2,3] to supply fundamental explanations, in spite of an unparalleled accumulation of empirical test results. Most of these are on strength, although the data on other aspects are not meager. Such data have served their useful function in supplying the necessary basis for safe specifications and reasonably satisfactory use, but they have contributed little toward real understanding of the behavior of the concrete or toward supplying a basis for generalizations.

For the past 15 yr., while engaged in a variety of researches designed, for the most part, to determine the effect of variables upon strengths, the authors have accumulated what appeared to be, for the moment, irrelevant data, including complete stress-strain diagrams on tests from which only ultimate strengths were then desired. While localized bits of this evidence have been scanned from time to time, only recently has a systematic study of the data been attempted with a view to developing a workable basis for the comparison of the fundamental stress-strain behavior of specimens which differ widely from one another in strength, stiffness and amount of deformation. The studies have shown the existence of remarkable agreements and unsuspected trends.

The purpose of this paper is, then, to illustrate and explain a basis for comparisons and to present as supporting evidence a few representative cases selected from among the many available. Extreme or contrasting series were selected the better to illustrate the wide range over which the trends or the similarities exist. While such trends as are here shown may be expected to give rise to interesting speculations, the authors have decided to confine themselves to the presentation of representative evidence and a summary of what appears to be shown definitely by it. Numerical values or percentages for compressive strength, Young's modulus, proportional limit, deformations and related data appear in Table I.

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[1] **Head, and Associate Professor, respectively, Department of Theoretical and Applied Mechanics, Iowa State College, Ames, Iowa.**

[2] F. E. Richart, Anton Brandtzaeg and R. L. Brown, "The Failure of Plain and Spirally Reinforced Concrete in Compression," *Bulletin 190*, Engineering Experiment Station, University of Illinois (1929).

[3] Anton Brandtzaeg, "Failure of a Material Composed of Non-Isotropic Elements," Kommission Hos F. Bruns Bokhandel, Trondhjem, Norway (1927).

TABLE I.—TEST DATA.

Curve and Case	Proportion, by Weight	Water-Cement Ratio, by Volume	Slump, in.	Age of Test	Curing and Test Condition[a]	Compressive Strength, lb. per sq. in.	Young's Modulus, lb. per sq. in., × 10⁶	Proportional Limit, percentage of ultimate	Unit Strain at Indicated Percentage of Ultimate Strength × 10⁻⁴					See Figure	Curve and Case
									25 per cent	50 per cent	75 per cent	95 per cent	100 per cent		
SERIES 1, 1923, ILLINOIS, 6 BY 12-IN. CYLINDERS															
A	1:2.6	0.37	0.0	28 day	S	1 745	2.78	28.7	1.6	3.7	6.4	10.2	15.5	2	A
B		0.44	0.0			3 450	4.93	37.6	1.7	3.5	5.8	8.8	14.7	2	B
C		0.49	0.0			5 085	5.32	49.3	2.5	5.4	9.0	...	...	..	C
D		0.54	0.1			4 270	4.16	23.4	2.5	5.6	9.9	17.0	...	2	D
E		0.61	1.8			4 690	4.45	25.6	2.6	5.6	10.3	...	...	..	E
F		0.68	8.7			3 955	4.00	17.7	2.5	5.5	9.4	14.8	18.2	2	F
G		0.76	9.7			3 385	3.85	14.7	2.3	4.8	8.8	13.7	...	2	G
H		0.85	too wet			2 602	3.43	19.3	1.9	4.3	7.5	12.2	18.0	2	H
SERIES 2, 1926, COLORADO, 2 BY 4-IN. CYLINDERS															
I	Neat	0.40	Small Batches	4.5 yr.	AD	5 220	2.04	89.1	6.4	12.7	19.1	25.1	28.9	3, 7	I
J	Neat	0.60				4 330	1.51	78.5	7.0	14.0	21.0	27.2	30.4	3	J
K	1:1	0.80				2 070	1.53	72.5	3.4	6.8	10.3	14.1	15.1	3	K
L	1:1.5	0.80				2 420	2.37	80.6	2.5	5.0	7.5	11.2	13.9	3	L
M	1:2.5	0.80				1 600	1.91	53.1	2.1	4.2	6.9	10.1	11.9	3	M
N	1:3.0	0.80				1 100	2.15	68.1	1.3	2.6	4.0	6.2	7.3	3	N
SERIES 3, 1930, COLORADO, 3 BY 6-IN. CYLINDERS															
O	Neat	0.63	Small Batches	9 mo.	AD	8 335	2.00	49.2	10.4	22.2	34.6	48.6	51.2	..	O
P	Neat	0.63		9 mo.	AW	5 825	2.19	79.0	6.6	13.3	20.1	26.3	28.7	..	P
SERIES 4, 1931, COLORADO, 6 BY 12-IN. CYLINDERS															
Q	1:2.5	1.00	8.5	7 day	S	2 830	2.10	38.9	3.4	7.0	11.8	18.3	22.6	5	Q
R	1:2.5	1.00	8.5	28 day	S	4 650	3.02	23.7	4.0	8.4	14.3	20.4	22.3	5, 7	R
S	1:2.5:4	1.00	0.5	28 day	S	3 150	2.09	28.6	3.8	8.4	16.0	29.4	35.7	7	S
T	1:3:5	1.20	0.4	28 day	S	2 200	1.75	79.5	3.3	7.8	16.6	34.4	49.9	7	T
SERIES 5, 1935–1936, IOWA, 2 BY 2 BY 4-IN. PRISMS															
U	1:1.5	0.60	9.5	1 yr.	AD	5 275	3.35	48.8	3.9	7.9	13.1	19.7	26.2	4	U
V	1:1.5	0.60	9.5	1 yr.	AW	4 705	3.35	51.0	3.6	7.2	11.7	17.6	23.8	4	V
W	1:1.5	0.60	9.5	1 yr.	SD	13 470	4.86	45.5	7.0	14.1	22.8	33.4	39.9	4	W
X	1:1.5	0.60	9.5	1 yr.	S	10 970	4.79	41.9	5.7	11.8	19.7	29.3	37.4	4, 6, 5	X
Y	1:1.5	0.60	9.5	28 day	S	7 560	4.42	43.2	4.3	8.8	15.0	23.9	30.9	5	Y
Z	1:2.75	0.80	9.5	1 yr.	S	7 065	4.59	56.3	3.9	7.7	12.9	19.8	25.9	6	Z
AA	1:3.5	0.90	7.0	1 yr.	S	4 560	4.31	43.9	2.7	5.5	9.4	15.0	19.8	1, 6	AA
BB	1:4.25	1.05	6.0	1 yr.	S	3 800	4.15	46.8	2.3	4.8	8.5	14.2	19.6	6	BB

[a] S = standard cured, wet at test; AD = air cured, dry at test; AW = air cured, saturated at test; SD = standard cured, air dry at test.

DATA

Each line of Table I covers one case or condition and usually represents the mean result from two to four companion specimens, although in a few cases a single specimen is represented. Most, but not all, of the cases listed appear in the accompanying illustrations and some appear on more than one illustration as may be noted by reference to Table I. The identifying letter for case designation carries through the paper and identifies the specimen on any figure in which it appears.

Some supplementary explanations may be in order relative to the five series listed:

Series 1 constitutes one bit of a rather extensive thesis study by the senior author[1] in the Theoretical and Applied Mechanics Department of the University of Illinois during the summer of 1923. He is especially indebted to Professors Talbot, Richart, and Brown for the unstinted assistance, supervision, and resources placed at his disposal. Universal portland cement and a natural sand from Attica, Ind. (0 to 4 grading), were used.

Series 2 consists of a few cases selected from a more extensive small-specimen series on neat cement and sand mortars in which Colorado portland cement and standard Ottawa (20 to 30) sand were used. W. L. Eager and Smith Ketchum, then students in civil engineering, assisted in the casting and testing of the specimens of this series.

Series 3 consists of a few specimens from a series, mostly of neat cement specimens, in which Colorado portland cement was used after having been stored about two years in paper-lined, covered galvanized cans.

Series 4 is made up of a few specimens from a rather extensive preliminary investigation of materials and mixtures for the Eleven Mile Canyon Dam built by the City of Denver. The fine aggregates were crushed granite screenings (0 to No. 4) from the dam site and the coarse aggregate was crushed granite $\frac{1}{4}$ to 1-in. grading. Colorado portland cement was used. Messrs. W. H. Thoman and Riley Cass assisted in the tests.

In series 5, case Z represents the mean of several companion specimens of an extensive curing series cast in 1935.[2] All other cases listed in this series are from the same lot of materials but were cast in 1936 in connection with pull-out bond tests.[3] The cement was a leading Iowa brand purchased

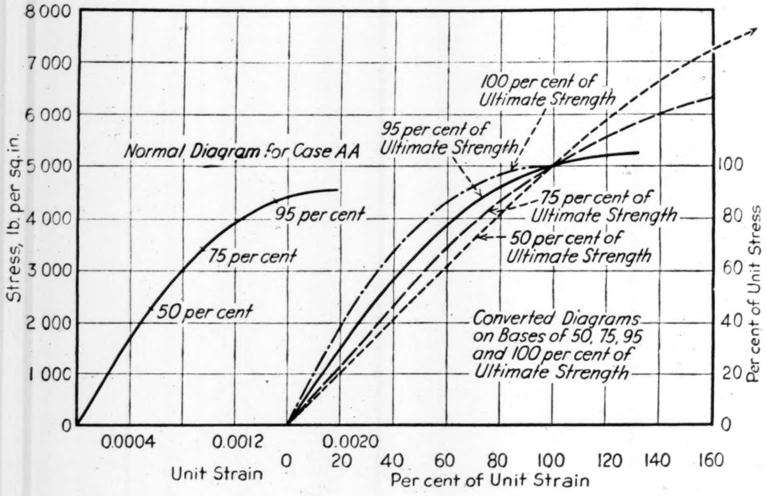

FIG. 1.—Illustrative Stress-Strain Diagrams.

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[1] H. J. Gilkey, "Coarse Aggregates and the Properties of Concrete," Unpublished Master's Thesis, Department of Theoretical and Applied Mechanics, University of Illinois (1923).

[2] H. J. Gilkey, "The Moist Curing of Concrete," *Engineering News-Record*, Vol. 119, October 14, 1937, p. 630.

[3] H. J. Gilkey and G. C. Ernst, "Pullout Tests for Bond Resistance of High Elastic Limit Steel Bars," *Proceedings*, Highway Research Board, Vol. 16, p. 82 (1936).

locally and the sand was clean, of 0 to No. 4 grading, from the Des Moines River, and somewhat lacking in fines. The prismatic, side-cast specimens, 2 by 2 by 4 in., have been shown to give strength results comparable to those secured from cylinders, and there is no evidence to indicate a difference in stress-strain behavior.[1,2] Mr. G. C. Ernst and S. J. Chamberlin assisted in these tests.

BASIS FOR COMPARISON OF STRESS-STRAIN DIAGRAMS

Figure 1 illustrates the basis upon which the behavior of radically different specimens may be compared more directly than by means of the conventional stress-strain diagram.

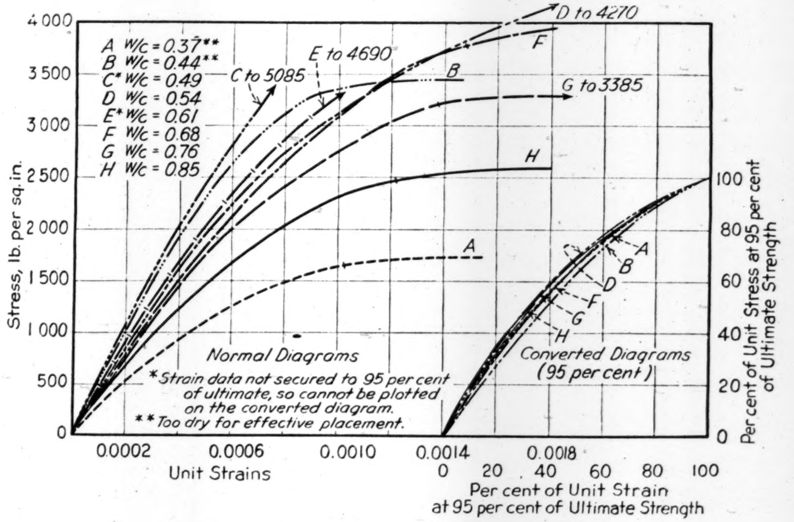

FIG. 2.—Effect of Water-Cement Ratio.
Series No. 1. (Letters correspond to those in Table I.)

Since most of the usual standard-cured 28-day concretes and mortars show an ultimate compressive unit strain of about 0.0020 the first method of comparison attempted was to plot percentages of ultimate stress against the observed corresponding unit strains (actual, not percentage). For different mixtures and for ages other than 28 days, and especially for different test conditions (saturated, air-dry, etc.), the variation in ultimate unit strain was too great to net satisfactory comparisons. A representative range can be noted by reference to Table I.

When both strength and strain were put on a percentage basis, the comparisons were more satisfactory,[3] but the drawback lay in the unreliability of values secured for ultimate unit strain. Near the ultimate load in a compression test, the specimen is breaking down rapidly. The strainometer dial is racing at virtually constant load which produces the horizontal top shown on the normal stress-strain diagram at the left of Fig. 1. While the maximum load is quite a definite value, the maximum strain is indefinite, and what would be considered the maximum would differ greatly for different types of specimens (lean, weak and soft, and rich, strong and brittle, etc.).

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[1] H. J. Gilkey and H. Walter Leavitt, "Comparisons of Different Types of Specimens for Compression Tests of Mortars," *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 281 (1935).

[2] See footnote 2, p. 320.

[3] A. N. Talbot used this device in deriving the parabolic formulas for reinforced concrete beam design. He assumed an ultimate compressive unit deformation of 0.0020 for concrete. See Fig. 1, p. 8 of *Bulletin 4*, University of Illinois Engineering Experiment Station on "Tests of Reinforced Concrete Beams, Series of 1905."

For the method of test employed[1] the strain corresponding to a stress, slightly below the ultimate, is a definite quantity. It seemed logical, therefore, to adopt 95 per cent of the ultimate stress as a proper datum for comparisons on a percentage basis. Thus the stress and the strain at 95 per cent of the ultimate strength are used for the 100 per cent point or upper terminus where all the curves must cross one another. That is, all stresses are plotted as percentages of 95 per cent of the ultimate strength and the corresponding strains are plotted as percentages of the unit strain at 95 per cent of the ultimate strength.

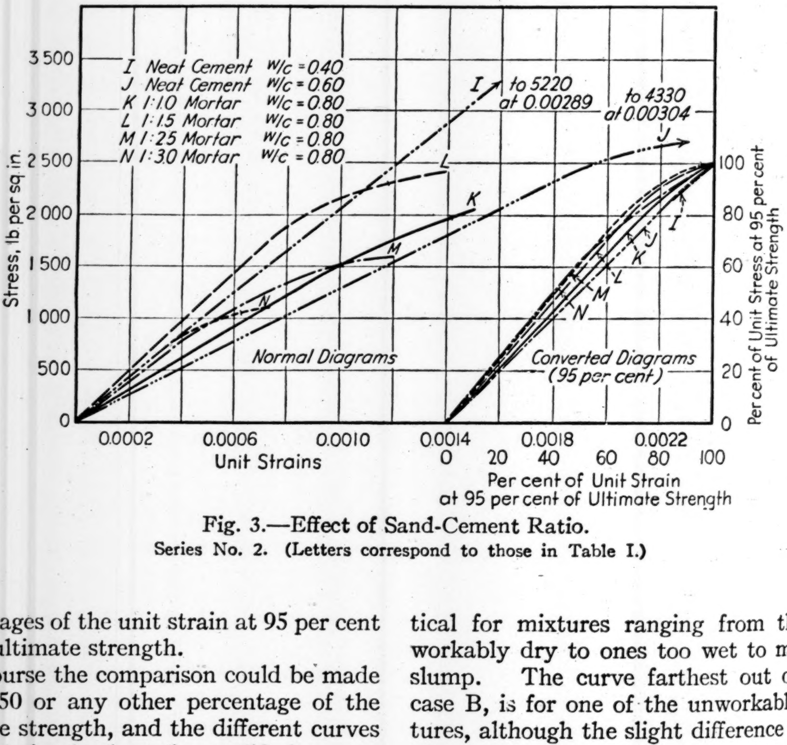

Fig. 3.—Effect of Sand-Cement Ratio.
Series No. 2. (Letters correspond to those in Table I.)

Of course the comparison could be made at 75, 50 or any other percentage of the ultimate strength, and the different curves of Fig. 1 simply show the modified or converted stress-strain diagram for case AA using different percentages of the ultimate strength. Where the strainometers are removed or disconnected prior to failure, it would be necessary to make the comparisons at some percentage lower than 95. As can be noted in Table I, values of strain were not secured for either case C or E at 95 per cent of the ultimate and these cases could not therefore be plotted on the converted diagram of Fig. 2. Figure 1 shows that differences in stress-strain behavior are magnified as the junction point is raised to a higher percentage of the ultimate strength.

DISCUSSION OF RESULTS

For the water-cement ratio series of Fig. 2, the converted diagrams show the basic stress-strain behavior to be virtually identical for mixtures ranging from the unworkably dry to ones too wet to measure slump. The curve farthest out of line, case B, is for one of the unworkable mixtures, although the slight difference shown is more likely due to chance than to the lack of workability, since case A (even drier) does line up with the others. A duplicate series for a slightly different sand-cement ratio (1:2.7) gave almost identical indications, the entire group of converted diagrams falling squarely upon the group shown on Fig. 2.

Quite in contrast with the surprising agreement of Fig. 2 is the moderate but pronounced and definite trend of Fig. 3, showing how the converted stress-strain diagram tends to bow increasingly to the left as the sand-cement ratio increases. Thus a range of water-cement ratio that produced great variation in strength and stiffness (series 1, Table I) shows no discernible difference in basic stress-strain behavior, whereas a variation in sand-cement ratio which produces less striking differences in normal stress-strain behavior, shows a discernible and consistent trend when converted to the percentage basis.

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[1] For all of these tests, records of strain were secured without interrupting the test or varying the rate of load application.

Figure 4 (series 5) shows that variation in air and water curing has no discernible influence upon fundamental stress-strain behavior. Neither does the saturated *versus* the dry condition at test produce a visible difference.

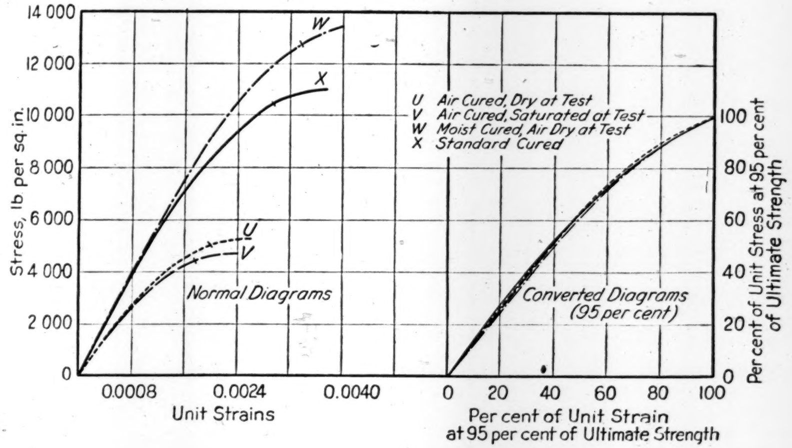

FIG. 4.—Effect of Curing and of Dry or Saturated Condition at Test.
Series No. 5. (Letters correspond to those in Table I.)

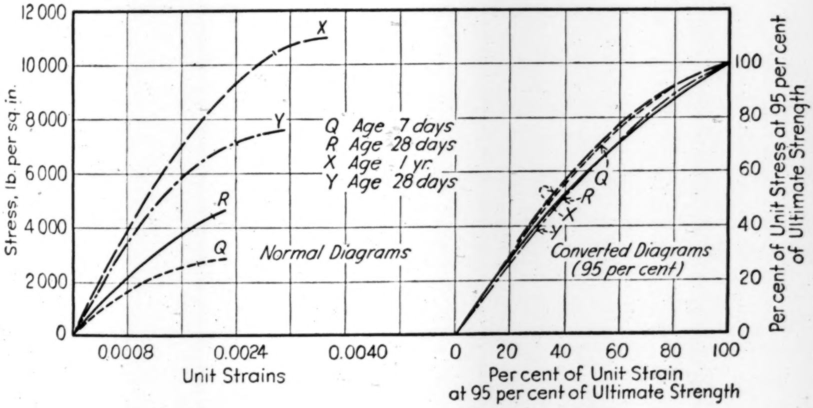

FIG. 5.—Effect of Age (Standard Curing).
Series Nos. 4 and 5. (Letters correspond to those in Table I.)

While the converted curves of Fig. 5 (series 4 and 5) show a greater spread than appears on Figs. 2 or 4, a second glance seems to brand the difference as accidental rather than fundamental. Converted curves *Q* and *R* appear to indicate that increased age (7 to 28 days) carries the curve to the right. On the other hand, converted curves *X* and *Y* indicate a reverse trend for the range of 28 days to 1 yr. The two 28-day curves *R* and *Y* coincide, but perhaps the more interesting observation is to note the coincidence of the 7-day and 1-yr. curves.

The relatively small and apparently chance deviations of Fig. 5 (all of which occur within the respective series, rather than between series) are the more striking when one realizes that the series 4 tests were on 6 by 12-in. specimens from Colorado cement and crushed granite screenings and were made in 1931, whereas series 5 was on 2 by 2 by 4-in. side-cast prisms from Iowa cement and Des Moines River natural sand and was cast in 1935. One might, however, suspect that the compounding of variables had resulted in a compensation of effects, but supporting data (not included in this paper) seem to indicate that such is not the case. The conclusion from Fig. 5 seems rather definitely to be that the period of standard curing does not influence fundamental stress-strain behavior.

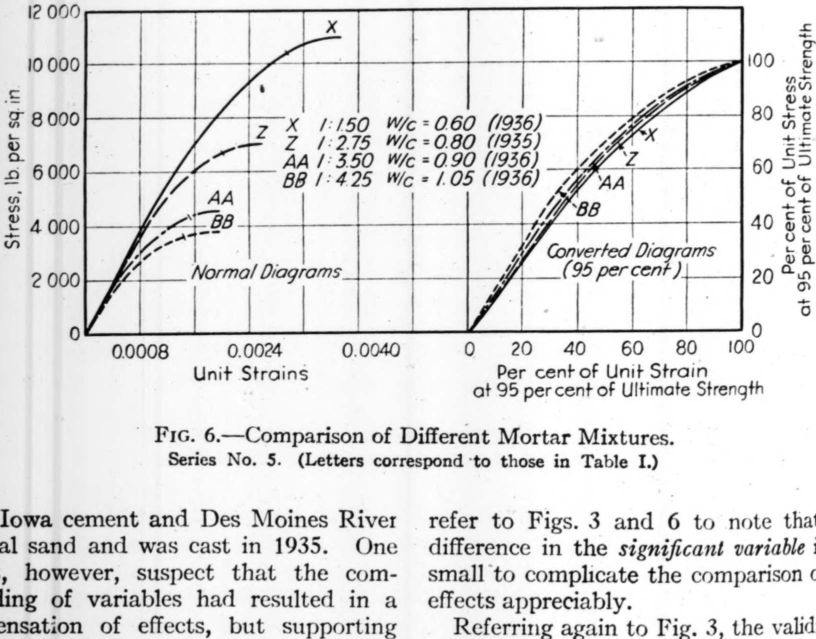

FIG. 6.—Comparison of Different Mortar Mixtures.
Series No. 5. (Letters correspond to those in Table I.)

Figure 6 (series 5) shows remarkably close agreement among the four widely different mortar mixtures. Both the water-cement ratio and sand-cement ratio enter as variables in this comparison. From the indications of series 1 (Fig. 2) water-cement ratio differences should not show up on the converted diagrams, whereas the differences in sand-cement ratio should, according to Fig. 3, produce a discernible trend. It seems reasonable to conclude that the slight trend shown is due to the variations in sand-cement ratio, which conclusion is supported by the perfect sequence of arrangement from case X to case BB, as sand-cement ratios increase.

Reverting now to Fig. 5, the heretofore unmentioned difference in the sand-cement ratios of the two series 4 specimens and the two series 5 specimens (sand-cement ratios 2.5 and 1.5, respectively), one has but to refer to Figs. 3 and 6 to note that this difference in the ***significant variable*** is too small to complicate the comparison of age effects appreciably.

Referring again to Fig. 3, the validity of comparing neat cements at 0.40 and 0.60 water-cement ratios with sand-cement mixtures at 0.80 water-cement ratio was established in several ways. Figure 2 shows the lack of water-cement ratio effects for sand-cement mixtures. The neat cement specimens of series 3, and others not included, supplied the supporting evidence required. Figures 4 and 5 supplied the necessary evidence relative to differences in age, curing condition and saturated or dry condition at test. Moreover, supplementary evidence supported all of these observations.

Figure 7 is a summary diagram on which is shown the trend from neat cement, to mortar, to rich concrete, to lean concrete, all in a perfect sequence. It summarizes the findings and projects them from the more or less purely academic field of mortars to the practical field of concrete of ordinary structural quality.

For the range of mixtures covered by the paper, Table I supplies interesting comparisons of some factors not appearing on the curves. The values for modulus of elasticity and the ultimate strength show the general but indefinite relationship between strength and stiffness, which is in accord with most efforts that have been made to correlate the two.

The proportional limit, always ill-defined for concrete, is rarely as small as 25 per cent of the ultimate strength. The values for series 1 are less refined than are those for the other series, and this fact may or may not explain the relatively low percentage values of proportional limit for some of those cases.

The numerical values of unit strain at the several percentages of the ultimate strength supply interesting data for comparison.

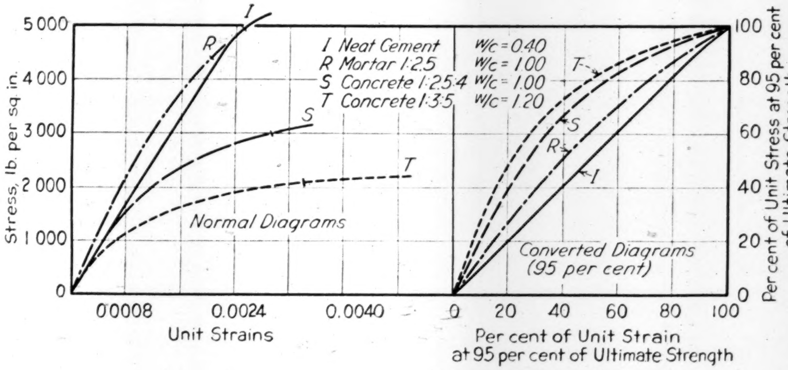

FIG. 7.—Comparison of Neat Cements, Mortars, and Concrete.
Series No. 4 (except neat cement of Series No. 2).
(Letters correspond to those in Table I.)

CONCLUSIONS

1. Comparisons of stress-strain diagrams on the two-way percentage basis appear to be an excellent means for studying fundamental stress-strain behavior.

2. Such comparisons are most effective for emphasizing differences if they can be made at a base stress just slightly below the ultimate strength. The arbitrary selection of 95 per cent for these tests was satisfactory.

3. These results indicate that variations in water-cement ratio, curing, and age introduce little if any difference in the fundamental stress-strain behavior, but they indicate that variations in amount of aggregate do produce consistent differences in stress-strain behavior.

4. The differences due to the aggregate carry through consistently from neat cement to lean concrete, the converted diagram being virtually a straight line for the neat cement and becoming more curved and convex to the left as the amount of aggregate is increased.

5. This paper does not include any results on effects of size of aggregate, the size variations present being incidental. That phase is reserved for possible future study.

6. The converted diagrams cannot be used directly as a basis for judging such

items as relative stiffness, although relationships based upon the converted diagrams can be derived.

7. For most of the cases covered, the proportional limit was well above 25 per cent of the ultimate strength, which indicates that secant values of Young's modulus at from one-fourth to one-third the ultimate strength should be relatively correct for concrete generally.

8. For the wide range of mixtures, materials and conditions chosen, the results are remarkably uniform and consistent. Further study along similar lines should supply a basis for materially extending our knowledge regarding the stress-strain behavior as well as the breakdown process for a heterogeneous material such as concrete.

Acknowledgments:

These data are reported as one phase of a project of the Iowa Engineering Experiment Station, T. R. Agg, Director. The authors are indebted, for assistance in working up the data, to R. W. Beal and Mrs. Glenn Murphy.

DISCUSSION

MR. GERALD PICKETT[1] (*by letter*).—From a mathematical point of view, similarity of the converted diagrams would indicate some similarity of the mathematical equation representing the curve. For example, if the normal diagrams of two materials are parabolas, their converted diagrams would be identical. However, considerable variation in equations is possible with only slight difference in curve. An illustration of this is the well-known method of approximating the deflection of a simple beam by means of a sine curve, although the actual moments and shears may be widely different from those necessary to give a sine curve. Since, from Fig. 1, the 95 per cent of ultimate curve differs considerably from the 100 per cent of ultimate curve, it seems possible that a small error in finding the 95 per cent point on the normal diagram might be the chief factor in causing difference in the converted diagram.

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[1] Associate Professor of Applied Mechanics, Kansas State College of Agriculture and Applied Science, Manhattan, Kans.

APPENDIX II

FACTORS AFFECTING THE TESTING OF CONCRETE AGGREGATE DURABILITY

By Charles E. Wuerpel[1]

Synopsis

Presented herein are the results of a series of tests of the characteristics of three methods of testing concrete aggregate durability, the magnesium sulfate and the freezing-and-thawing methods of testing unconfined aggregate and the freezing and thawing of aggregate confined in concrete. The specimens for the program include sixteen sands and twelve gravels from widely distributed points in the United States.

The series demonstrates the marked influence of the *type* of container and the procedure technique upon the results of the magnesium-sulfate accelerated soundness test of fine aggregate.

The magnesium-sulfate test of fine aggregate indicates considerable acceleration over a freezing-and-thawing test, but there is little definite relationship between the severity of the two.

The magnesium-sulfate test of coarse aggregate is shown to be only slightly more severe than a freezing-and-thawing test. With certain aggregates, frost action was more severe than magnesium sulfate.

Parallel freezing-and-thawing tests of concrete beams show the comparison of inelastic length increase, weight loss and total failure with results of the magnesium-sulfate and the freezing-and-thawing tests of similar unconfined coarse aggregates.

In spite of the enormous amount of scientific attention which has been devoted to the problems surrounding the manufacture of concrete, no adequate standards for testing the durability of concrete aggregate have been developed and adopted by the Society.

A suggested method for making a freezing-and-thawing test of concrete and concrete aggregate was published by this Society[2] and a tentative method has been adopted for making an accelerated soundness test of fine and coarse aggregate.[3] However, it has been the experience of the author that practically every testing agency still uses its own procedure. The result is a general confusion in this very important phase in the manufacture of durable concrete.

The engineers responsible for the design and construction of projects which will be subjected to varying degrees of climatic attack are lost in a maze of indefinite allusions to sodium sulfate, magnesium sulfate, freezing and thawing, numbers of cycles and percentages of loss in making their decisions as to test requirements for concrete aggregate. Each source from which they seek information adds something to the confusion by making differing recommendations.

The author hopes that the data contained in this paper may contribute something toward the lessening of the confusion and lead to more definite standards.

The northeastern portion of the United States is surfaced with glacial gravels of a widely varying geological nature. The degree to which the rocks within this territory have been altered by metamorphism and weathering makes the careful testing of their soundness imperative. The severity of the climatic attack, in the frequent alternations of freezing and thawing, adds further to the necessity for the judicious choice of aggregate for exposed concrete.

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[1] Engineer in Charge, Central Concrete Laboratory, U. S. Military Academy, West Point, N. Y.

[2] Proposed Method of Testing Concrete and Concrete Aggregates by Freezing and Thawing, *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 364 (1932).

[3] Tentative Method of Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (C 88 – 37 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 804 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 604.

Faced with the task of locating aggregate of satisfactory durability, first for the Passamaquoddy project in Maine and more recently for the proposed flood control structures in New York and the New England States, the author placed greatest reliance upon the magnesium-sulfate accelerated soundness test as the criterion of acceptability. The choice was based upon the following assumptions:

1. Magnesium sulfate was a more stable compound, at ordinary temperatures, than sodium sulfate and less expensive to use.

2. The magnesium-sulfate test simulated frost action and afforded a means for obtaining an accelerated result of resistance to frost action.

3. One cycle of the magnesium-sulfate test was roughly equal to seven cycles of laboratory freezing and thawing.

4. That, in addition to this acceleration, the magnesium-sulfate test required less equipment than freezing and thawing, and was more economical to make.

The procedure adopted was in accordance with the present A.S.T.M. Tentative Method of Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (C 88 - 37 T),[3] and was executed in the following manner:

Coarse Aggregate:

Representative 1000-g. samples of each of three sizes of the gravel were selected, washed, dried and immersed in a saturated solution (1 part of $MgSO_4 \cdot 7H_2O$ to 1 part of water, by weight) of magnesium sulfate. The receptacles initially used were round, shallow metal pans. After 17 hr. the sulfate solution was poured off and the samples were placed in a drying oven at a controlled temperature of 105 C. for 6 hr. The samples were then removed from the oven and permitted to cool for 1 hr. after which they were returned to the sulfate solution for resaturation for 17 hr. This procedure was repeated for 10 cycles. Upon completion of the tenth cycle the samples were carefully washed, dried and separately rescreened over the original sieves. That portion of the sample which passed through

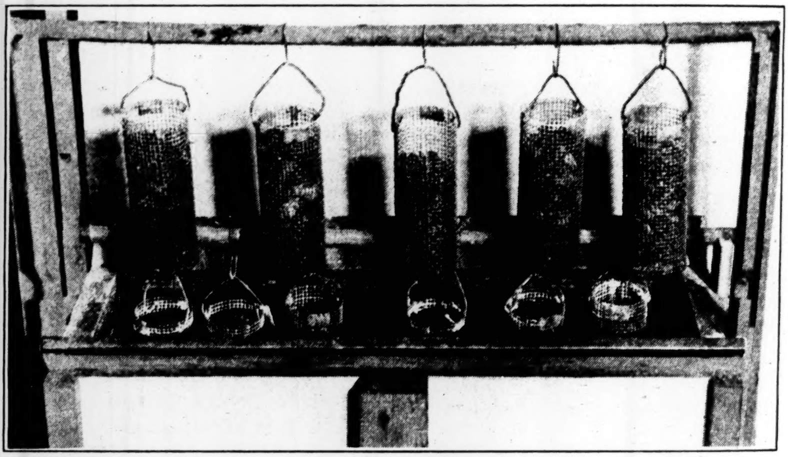

FIG. 1.—Magnesium-Sulfate Immersion Vat. Coarse aggregate. Showing immersed and draining cylindrical containers.

the meshes of the screen constituted the loss. The individual losses of the three sizes were prorated in accordance with the normal grading of the gravel and the weighted average loss was computed.

With the severe condition of exposure to frost action in mind, the permissible loss was arbitrarily set at 10 per cent by weight.

The principal faults that were found with this procedure were the large amount of space required for the pans used, the adulteration of the sulfate solution by the fine detritus of the disintegrating aggregate particles and the general untidiness of the procedure.

The technique and equipment now used by the laboratory eliminates those faults and provides an improved procedure. The concordance of results has been improved by increasing the weight of the sample (in the ½-in. and 1-in. sizes) to 2000 g. The pans have been replaced by cylindrical baskets 3 in. in diameter and 10 in. in height made of No. 4 mesh galvanized wire screen. The baskets are suspended in a vat containing a large quantity of the sulfate solution for the saturation period. Prior to drying, the baskets are elevated and suspended above the vat, as shown in Fig. 1, and permitted to drain for 10 min. The drying is accomplished in a homemade oven (Fig. 2) large enough to hold 32 baskets.

This procedure obviated the necessity for handling small amounts of the solution or removing the samples from their containers during the test. The large amount of sulfate solution in the vat is easily maintained at the proper degree of concentration (specific gravity 1.275) by daily check with a hydrometer. The detritus from the disintegrating samples settles to the bottom of the vat and does not interfere with the test. The vat is cleaned biweekly.

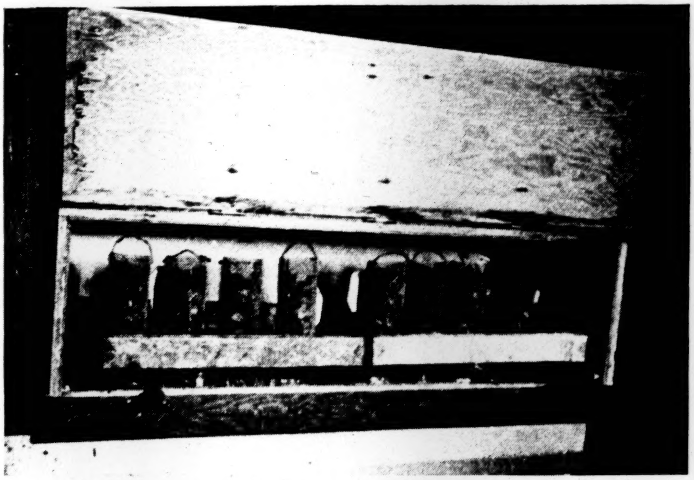

FIG. 2.—Dehydrating Coarse Aggregate Samples in Large Oven. Magnesium-sulfate test.

The final washing of the samples is facilitated by immersion in a vat through which warm water flows. The washing is continued until titration of the water with barium chloride indicates the complete removal of the sulfate.

Fine Aggregate:

Crucible Method.—The problems involved in the testing of fine aggregate were not so susceptible of solution. The original procedure was as follows:

One-hundred-gram samples were selected from each of the following grain sizes of the thoroughly dried sand: Nos. 8, 16, 28, 48 and 100 (Tyler series). The samples were placed in porcelain crucibles containing sufficient sulfate solution to cover them to a depth of about ½ in. After the initial saturation period of 17 hr., as much of the solution was removed from the crucible as could be by decanting and eye-dropper suction. The crucibles were then placed in an oven at a controlled temperature of 105 C. for 6 hr. Upon completion of the dehydrating period, the crucibles were permitted to cool for 1 hr., after which the proper amount of sulfate solution was introduced into the crucible and the second saturation period was begun. Upon completion of the tenth cycle the crucibles were carefully boiled in water for a time necessary to remove all traces of the sulfate from the sample. The samples were then dried and separately rescreened over the original sieves and the individual losses recorded. The losses were prorated in accordance with the natural grading of the fine aggregate to determine the weighted loss for the sample.

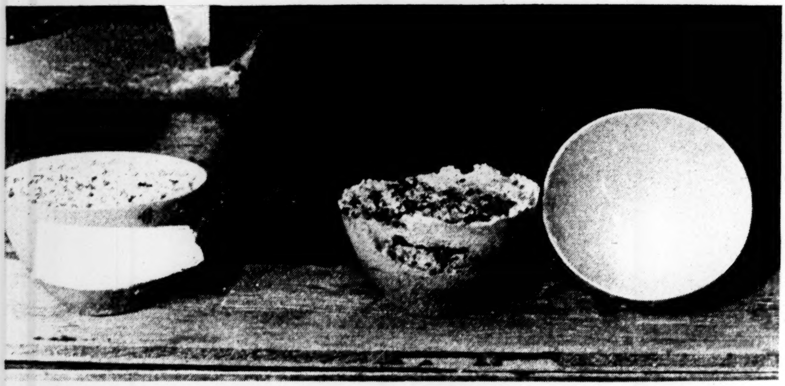

FIG. 3.—Showing Severe Caking in Fine Aggregate Crucible Procedure.

The faults to be found with the above procedure are important and manifold, but they all seem to spring from the single fact that all surplus solution is not removed from the sample before dehydration. A number of devices, including gravity drainage through perforated bottoms and suction and syphoning through capillary tubes, were carefully tried in a futile attempt to withdraw all the surplus solution.

The presence of excess solution reflects itself in the procedure, as follows:

(*a*) The dehydrated salts on the surfaces of the particles gradually adds to the concentration of the solution in ensuing cycles. Efforts to compensate accurately for the presence of the excess salt are rarely successful.

(*b*) These surplus salts gradually cement the particles of the sample together in a hard mass which resists the free movement of the sulfate solution through the sample during the progressive cycles of the test. By the time the 10 cycles of the test are completed, the sample is usually so densely cemented that the removal of the sulfate requires vigorous boiling and agitation of the caked mass. A rather severe example of "caking" is illustrated in Fig. 3.

(*c*) It was found to be practically impossible to obtain rational results with the No. 100 grain size. After numerous attempts it was discontinued.

The presence of surplus sulfate in the crucible tests was felt to be responsible for the numerous erratic results which were obtained on identical samples of fine aggregate. The importance of the aggregate acceptance tests for which the laboratory was responsible made improvement imperative.

After numerous attempts to overcome the natural tendency of packed sand to retain a large amount of liquid on the surfaces of its individual particles, it became apparent that centrifugal force would be required to force out the surplus solution. A large electrically driven centrifuge was obtained and the procedure was modified as described below.

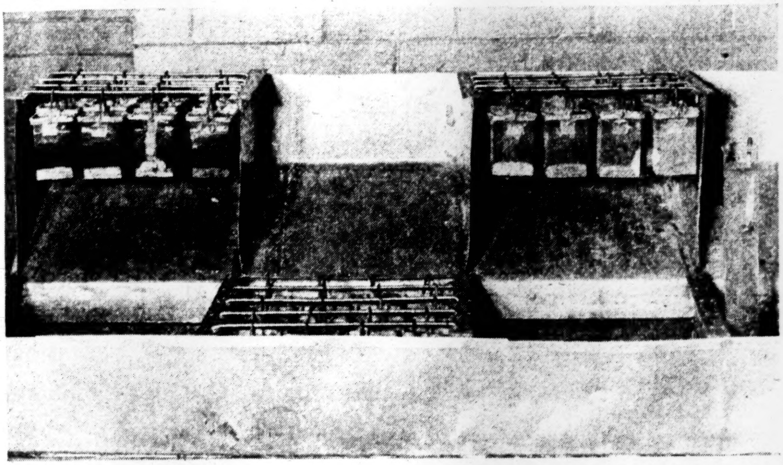

FIG. 4.—Magnesium-Sulfate Immersion Vat. Fine aggregate. Showing immersed and draining samples in basket gangs.

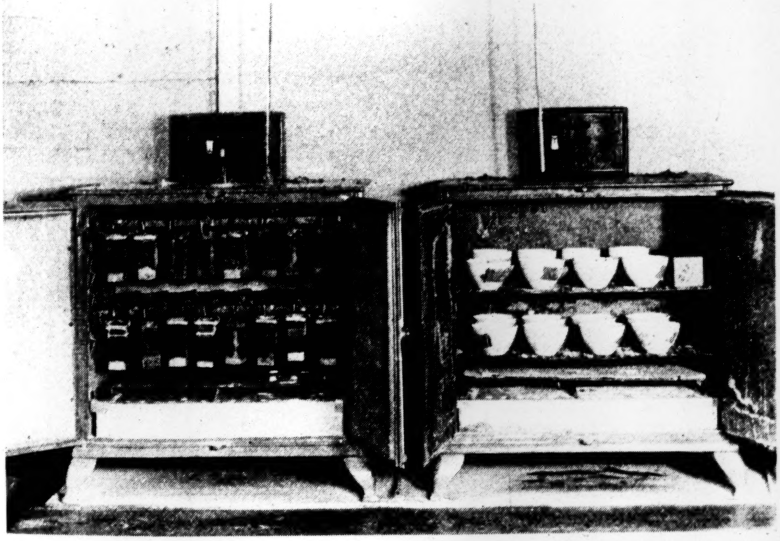

FIG. 5.—Dehydrating Fine Aggregate Samples in Ovens. Showing crucibles and basket gangs.

Centrifuge Method.—Special copper-screen wire baskets were constructed to fit the indentations on the rotor of the centrifuge. The capacity of each basket was made sufficient to hold a 100-g. sample with an adequate free-board. The wire meshes of each basket are one size smaller than the grain size to be tested in the basket, that is, the basket for the No. 8 grain size has No. 16 mesh; the basket for the No. 16 grain size has No. 28 mesh, etc.

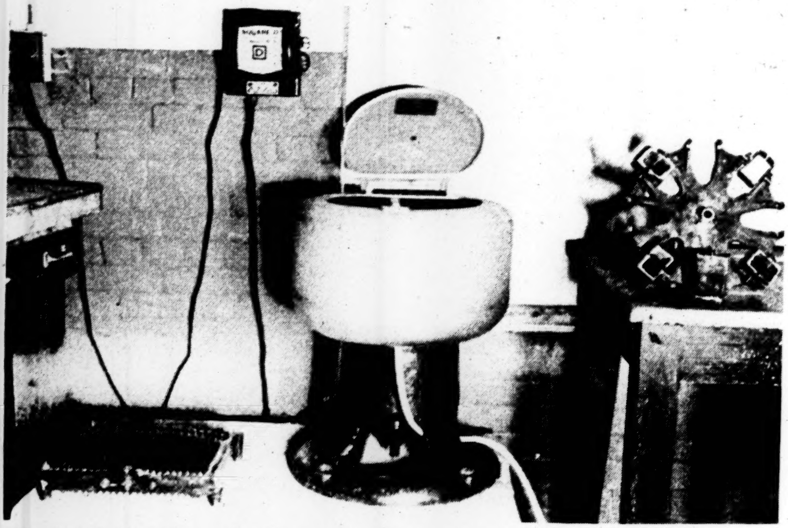

FIG. 6.—Enclosed Centrifuge for Removing Excess Solution from Baskets. Rotor removed for illustration.

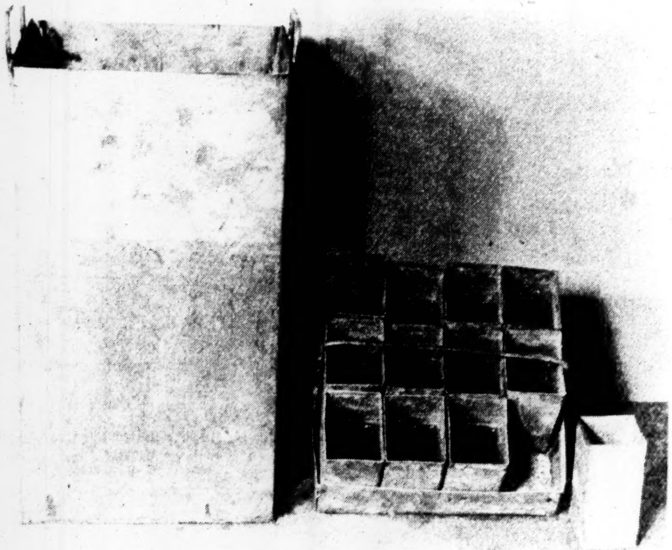

FIG. 7.—Freezing-and-Thawing Test. Fine aggregate. Showing nests of individual baskets and master container.

An immersion vat was built which permitted the gangs of baskets (4 to a gang) to be submerged in an easily controllable solution to a constant depth. The vat was equipped with a sloping bottom drain rack and sample hangers. The gangs of baskets are shown in Fig. 4 with some submerged and some in the drain position for the purpose of illustration. The concentration of the sulfate solution is checked daily by a hydrometer and adjusted, when necessary, by the addition of water or crystalline sulfate.

The drying ovens were equipped with hangers so that the maximum area of the basket gangs would be exposed for drying. The arrangement of the baskets in an oven is illustrated in Fig. 5.

Tests were commenced with this revised equipment in parallel with the tests being performed currently by the crucible method. The dehydrated and separated 100-g. samples of sand were placed in the baskets and immersed in the vat for 17 hr. after which they were elevated and permitted to drain for 10 min. on the rack. Each gang was then placed in the enclosed centrifuge (Fig. 6) and spun at a rate of approximately 900 r.p.m. for 1 min. The centrifuged gangs were then placed in the drying oven at a controlled temperature of 105 C. for 6 hr. After the drying period, the baskets were removed to the drain rack and permitted to cool before re-immersion for the second cycle.

The above procedure was found to be effective in the prevention of caking. After the tenth cycle the gangs were placed in warm flowing water until titration with barium chloride indicated complete removal of the sulfate from the samples.

The procedure was successful, but it was found that the results were widely divergent from those obtained by the crucible method that is, indicating anywhere from one fourth the loss obtained by crucible to an equivalent loss. With due consideration given to the fact that the disintegrating action of the test should be from expansive action *within* the pores and interstices of the particles of aggregate, it seems logical to assume that the centrifuge procedure afforded the purer test. However, the absolute lack of correlation between the two procedures provided an awkward obstacle to a simple change-over in acceptance requirements. By the time the centrifuge method had been adequately tested, several hundred samples of aggregate had been accepted or rejected on the basis of the crucible procedure.

Before any change was made in the acceptance policy of the laboratory, it was decided to investigate more carefully the

TABLE I.—LITHOLOGICAL DESCRIPTION OF COARSE AGGREGATES USED IN TEST SERIES.

TYPE	DESCRIPTION	PER CENT
NO-1	Chert; brown, buff, white, gray—derived from chert in limestone (probably)..	83.0
	Quartzite................	17.0
LI-1	Quartz pebbles...........	86.0
	Pebbles of siliceous gneiss..	14.0
HO-1	Vesicular basalt..........	100.0
BO-1	Exceedingly hard, fine grained, basalt-diorite family................	83.0
	Medium grained grano-diorite porphyrys.........	11.0
	Quartzite and quartz fragments.................	6.0
FP-1	Variety of fine-grained quartzite pebbles, well rounded; derived from metamorphic siliceous sedimentary rocks.......	78.0
	Quartz-feldspar-mica, gneiss of igneous derivation....	17.0
	Limestone...............	5.0
WA-1	Quartz from pegmatite intrusions................	33.0
	Great variety of crystalline schists (mica-chlorite-hornblende) and siliceous gneiss.................	77.0
BH-2	Fine-grained sandstone; appreciable amount of calcareous cement (weathered).................	88.0
	Quartz and gneiss fragments of glacial derivation.....	8.0
	Limestone...............	4.0
BC-28	Fine-grained sandstone; light green to deep red; thinly and weakly laminated in numerous cases.	86.0
	Limestone...............	14.0
BB-4	Argillaceous sandstone, fine grained (some calcareous cement); thinly laminated in numerous cases.	88.0
	Limestone...............	8.0
	Calcareous sandstone......	4.0
PWS-21	Siliceous mica-gneiss.......	41.0
	Quartz and few fragments of quartz schist...........	32.0
	Gneissoid granite (weathered).................	27.0
HB-3	Siliceous granitoid types, somewhat gneissoid......	45.0
	Dark granite, diorite-amphibolite type, generally gneissoid..............	55.0
DO-1	Glacial gravel; quartzitic sandstone; few fragments are metamorphic, red, gray, black............	52.0
	Granitic gneiss and few fragments of quartzitic schist	11.0
	Dark gray to light limestone; fine grained......	14.0
	Very hard fine-grained porphyrys (indeterminate)..	25.0

relation of the two procedures to each other and to the actual freezing and thawing of both fine and coarse aggregate. The latter was initially included with the idea of determining which of the two sulfate procedures approximated the degree of comparative severity which had been atrributed to the magnesium-sulfate soundness test.

TABLE II.—EFFECT OF TYPE OF PROCEDURE UPON RESULTS OF THE MAGNESIUM-SULFATE SOUNDNESS TEST OF FINE AGGREGATE. 10 CYCLES.

Sand	Origin Type	Procedure	Loss, per cent					Ratio of Severity, $\frac{Cr}{Ce}$
			Grain Size, 8	Grain Size, 14	Grain Size, 28	Grain Size, 50	Average	
LI-1	Silica	Crucible	3.0	1.5	5.5	2.0	3.0	....
		Centrifuge	2.0	3.0	1.0	1.0	1.75	1.70
NO-1	Silica	Crucible	5.0	3.5	3.0	5.5	4.25	....
		Centrifuge	3.1	2.5	5.0	6.2	4.20	1.00
FB-1	Granitic	Crucible	6.0	2.0	5.0	3.5	4.0	....
		Centrifuge	2.0	1 0	1.0	2.5	1.6	2.50
FF-18	Granitic	Crucible	5.5	5.5	5.5	4.5	5.7	....
		Centrifuge	2.0	2.0	1.5	1.5	1.75	3.25
FF-5	Granitic	Crucible	11.1	8.7	7.7	6.4	8.45	....
		Centrifuge	3.8	2.0	1.9	2.6	2.56	3.30
UN-1	Schistose	Crucible	21.0	15.0	11.4	10.7	14.3	....
		Centrifuge	9.4	5.9	4.8	7.4	6.9	2.10
DO-1	Dolomitic	Crucible	19.5	14.5	16.0	9.5	13.9	....
		Centrifuge	3.0	4.5	4.5	2.5	3.6	3.86
BA-9	Sandstone	Crucible	15.5	8.5	5.0	3.5	6.5	....
		Centrifuge	3.5	3.0	1.5	1.5	2.0	3.25
NA-1	Calcareous Sandstone	Crucible	27.0	13.0	7.0	8.0	11.8	....
		Centrifuge	10.5	8.0	3.5	4.5	5.9	2.00
BC-11	Sandstone	Crucible	17.0	17.5	7.5	6.0	12.2	....
		Centrifuge	5.0	4.0	2.5	2.0	3.4	3.60
BC-2	Argillaceous Sandstone	Crucible	13.5	13.5	14.0	14.5	13.7	....
		Centrifuge	3.0	4.0	6.0	7.0	5.0	2.70
BC-1	Argillaceous Sandstone	Crucible	9.0	16.0	19.0	17.0	16.5	....
		Centrifuge	6.0	7.5	10.5	9.5	8.2	2.00
BC-13	Argillaceous Sandstone	Crucible	19.25	15.0	14.7	14.4	16.0	....
		Centrifuge	3.6	4.0	4.7	3.7	4.0	4.00
BB-1	Argillaceous Sandstone	Crucible	14.0	18.8	22.0	24.0	19.7	....
		Centrifuge	7.5	11.0	12.0	13.0	10.9	1.80
BO-1	Igneous (basaltic)	Crucible	30.0	28.0	21.5	15.0	23.3	....
		Centrifuge	12.0	14.5	20.0	12.0	14.6	1.60
BA-10	Argillaceous Sandstone	Crucible	28.7	28.0	27.0	28.6	28.1	....
		Centrifuge	6.2	8.6	14.6	29.0	14.5	1.95
							Average.....	2.54

RESEARCH PROGRAM

For the purpose of the fine aggregate portion of the research, four large samples of sand were obtained from different localities within the North Atlantic Division of the U. S. Engineer Department. The sands had been previously analyzed and provided a typical cross-section of the questionable material within the territory. These sands were to be exhaustively tested by the three methods. In addition, it was decided to test twelve typical natural sands from widely distributed points within the United States to obtain information as to the influence of the mineral nature of the aggregate upon results of the test.

Twelve typical coarse aggregates from widely distributed points in the United States were chosen for the coarse aggregate portion of the research. The lithological description of the coarse aggregates is given in Table I.

Mineralogically, the sands varied from essentially pure silica to badly weathered and decomposed schists. The predominant geological origin of the sands are listed in Table II.

In addition to the durability tests of the unconfined aggregate, it was decided to investigate the reaction of eight of the types of coarse aggregate when confined in concrete. The concrete for this series of tests had the following unvaried characteristics:

Water-cement ratio	6.0 gal. per sack.
Cement factor	5.5 sacks per cubic yard.
Slump	1 to $2\frac{1}{2}$ in.
Aggregate ratio	34 per cent sand.
Maximum size coarse aggregate	1 in.
Fine aggregate	Silica sand. Fineness modulus, 3.1.
Cement	Portland (Federal Standard Specification SS-C-206).
Method of consolidation	External vibration. Specimens, in gangs of 3, vibrated in 2 layers for 45 sec. each.
Curing	16 days in water at 72 F.
Age at initial cycle	16 days.
Criterion of resistance	(*a*) Inelastic expansion as measured on a 10-in. span with a Whittemore strain gage. (*b*) Loss in weight.
Size of specimen	4 by 4 by 12-in. beams.
Number of specimens	6 beams from each type of aggregate.

Freezing-and-Thawing Procedure:

Fine Aggregate.—The samples of sands were separated into the same grain sizes (8, 14, 28 and 48) used for the sulfate procedures. However, 200 g. of each grain size were used instead of the 100 g. used in the sulfate tests. The separated and dried samples were placed in the zinc cans shown in Fig. 7 and covered with water to a depth of $\frac{1}{2}$ in. The samples were permitted to soak in this condition at a temperature of 70 F. ± 2 F. for 24 hr. after which they were nested in the trays and master containers (Fig. 7) and placed in the freezing chamber for 6 hr.

The freezing chamber was maintained at a temperature between 0 and −5 F., and the sand samples froze thoroughly in about 5 hr.

After the freezing period the master container was removed from the freezer and the gang trays were placed in a thawing vat in such a manner that the water which flowed through the vat (at a temperature between 55 and 65 F.) did not flow over the tops of the cans. The thawing period was 18 hr. This could have been shortened to 2 hr., but the limited capacity of the freezer, normal working hours and the necessity for freezing numerous concrete specimens during the night precluded the possibility of obtaining more than one full cycle in 24 hr.

The sand samples were dehydrated after each fifth cycle, sieved, weighed and the loss computed for each grain size. The test was continued until the loss exceeded 10 per cent or the number of cycles reached 70.

The sand samples were totally immersed in water through the entire period of the test.

Coarse Aggregate.—The procedure for freezing and thawing coarse aggregate was generally similar to that described for fine aggregate. Suitable galvanized iron cans were used; three pebble sizes were tested for each sample; the freezing-and-thawing periods were the same and the samples were constantly and totally immersed in water. Observation of loss was made after each fifth cycle, and the test was continued until the loss exceeded 10 per cent but for 15 cycles in any case. At the completion of the test, each particle of the coarse aggregate was inspected and progressive fractures or plane weaknesses were noted.

Freezing-and-thawing tests of coarse aggregate were made in duplicate or triplicate and each pebble size contained 1000 g.

Concrete Beams.—The 4 by 4 by 12-in. concrete beams described above were subjected to freezing and thawing in two conditions 16 days[4] after molding.

The six beams made from each type of aggregate were thoroughly saturated prior to the initial freezing. Three of the six beams were frozen in a completely immersed condition, and the other three were frozen in a saturated but *non*-immersed condition. The freezing period in each case was 18 hr., during which time the temperature of the specimens was reduced from between 65 and 70 F., to between 0 and −5 F. At the end of the freezing period, the beams were removed to the thawing tank for 6 hr. At the end of each fifth cycle, each beam was hand dried, weighed and the length of the gage span was observed with a 10-in. Whittemore strain gage.

To eliminate thermal errors due to temperature fluctuations in the thawing tank, companion beams for each type of aggregate were used to determine the thermal coefficient of expansion. The exact temperature of the beams, when read, was determined from the interior temperature of a dummy concrete cylinder, containing an accurate electrical resistance thermometer, which remained in the thawing tank throughout the program.

The freezing-and-thawing test was continued until the beams could be picked to pieces with the bare hands.

TABLE III.—COMPARISON OF SEVERITY AND CONCORDANCE OF METHODS OF TEST OF FINE AGGREGATE DURABILITY. SAND BC–13.

Test	Individual Losses, per cent					Average of Tests, per cent	Deviation, per cent	Average Deviation, per cent	Maximum Deviation, per cent
	Grain Size, 8	Grain Size, 14	Grain Size, 28	Grain Size, 50	Average				
CRUCIBLE METHOD (10 CYCLES)									
No. 1	20.50	17.50	....	18.50	18.80	....	17.5	....	....
No. 2	13.00	15.50	13.00	14.00	13.90	....	13.0	....	....
No. 3	19.50	17.00	16.00	15.50	17.00	....	6.2	....	....
No. 4	19.50	14.00	16.00	11.00	15.12	....	5.5	....	....
No. 5	19.50	15.00	16.00	15.50	16.75	....	4.7	....	....
No. 6	18.00	13.00	15.00	14.00	15.00	....	6.2	....	....
No. 7	24.78	12.75	12.15	12.30	15.50	....	3.2	....	....
Average	19.25	15.00	14.70	14.40	....	16.00	....	8.0	17.5
Maximum Deviation	32.50	16.70	17.00	28.50	....	....	....	....	....
CENTRIFUGE METHOD (SPEED 3 TO 10 CYCLES)									
No. 1	4.0	4.0	5.0	3.5	4.25	....	6.2	....	....
No. 2	3.0	4.5	5.0	3.5	4.00	....	0.0	....	....
No. 3	3.0	4.0	4.0	4.0	3.75	....	6.2	....	....
No. 4	3.5	4.0	4.0	4.0	3.87	....	3.2	....	....
No. 5	5.0	3.0	4.5	4.0	4.12	....	3.0	....	....
No. 6	3.0	4.5	5.0	3.5	4.00	....	0.0	....	....
No. 7	3.5	4.0	4.2	3.8	3.90	....	2.5	....	....
Average	3.6	4.0	4.7	3.7	....	4.00	....	3.1	6.2
Maximum Deviation	38.9	25.0	20.0	7.5	....	....	....	....	....
FREEZING-AND-THAWING TEST (70 CYCLES)									
No. 1	17.00	7.00	4.00	5.50	8.50	....	13.1	....	....
No. 2	22.50	11.00	4.00	4.00	10.37	....	6.1	....	....
No. 3	23.30	12.10	3.55	2.95	10.48	....	7.1	....	....
Average	20.90	10.20	3.85	4.15	....	9.78	....	8.8	13.1
Maximum Deviation	18.60	26.00	7.80	32.50	....	....	....	....	....

RATIO OF SEVERITY

METHOD OF TEST	LOSS	RATIO
Freezing-and-thawing	1.50	1
Centrifuge	4.0	2.67
Crucible	16.00	10.70

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[4] This early age was chosen to expedite the test and because, with a 14-day specified job-curing period, field concrete placed during the winter might well be exposed to freezing and thawing at this age.

DISCUSSION OF RESULTS

Fine Aggregate:

Tables III, IV, V, and VI contain the tabulated results of the three types of test conducted on the four principal fine aggregates used in the program. Analysis of these data indicate the following salient features:

TABLE IV.—COMPARISON OF SEVERITY AND CONCORDANCE OF METHODS OF TEST OF FINE AGGREGATE DURABILITY, SAND BA–S–10.

Test	Individual Losses, per cent					Average of Tests, per cent	Deviation, per cent	Average Deviation, per cent	Maximum Deviation, per cent
	Grain Size, 8	Grain Size, 14	Grain Size, 28	Grain Size, 50	Average				
CRUCIBLE METHOD (10 CYCLES)									
No. 1	27.50	30.00	30.00	34.00	30.40	....	8.20	....	....
No. 2	33.50	36.25	28.85	37.55	34.00	....	21.00	....	....
No. 3	32.25	35.53	29.15	29.10	31.50	....	12.10	....	....
No. 4	24.78	12.75	12.15	12.30	15.50	....	45.00	....	....
No. 5	27.00	28.50	27.50	26.50	27.20	....	3.20	....	....
No. 6	27.50	27.00	29.50	26.00	27.34	....	2.70	....	....
No. 7	28.80	26.40	32.25	35.00	30.60	....	8.90	....	....
Average	28.70	28.00	27.00	28.60	....	28.10	....	14.50	45.00
Maximum Deviation	16.70	54.40	53.10	57.00	....	....	....	....	....
CENTRIFUGE METHOD (SPEED 3 TO 10 CYCLES)									
No. 1	7.50	8.50	12.00	28.00	14.00	....	3.45	....	....
No. 2	5.10	7.20	12.80	30.00	13.75	....	5.16	....	....
No. 3	6.30	11.15	12.75	27.75	14.50	....	0.00	....	....
No. 4	5.00	6.00	10.50	25.00	14.00	....	3.45	....	....
No. 5	8.00	9.50	16.50	25.00	14.75	....	1.72	....	....
No. 6	5.50	9.00	14.00	31.50	15.00	....	3.45	....	....
No. 7	6.00	9.00	12.00	35.00	15.50	....	6.90	....	....
Average	6.20	8.62	14.36	29.00	....	14.50	....	3.45	6.9
Maximum Deviation	29.00	29.00	16.40	20.70	....	....	....	....	....
FREEZING-AND-THAWING TEST (70 CYCLES)									
No. 1	30.25	8.40	6.20	4.20	12.26	....	7.20	....	....
No. 2	16.40	15.30	5.60	5.05	10.40	....	9.00	....	....
No. 3	22.00	10.50	4.40	9.65	11.64	....	1.80	....	....
Average	22.90	11.40	5.40	6.30	....	11.43	....	6.00	9.00
Maximum Deviation	32.00	34.00	18.50	52.40	....	....	....	....	....

RATIO OF SEVERITY

METHOD OF TEST	LOSS	RATIO
Freezing-and-thawing	1.20	1.00
Centrifuge	14.50	12.00
Crucible	28.10	23.40

(*a*) *Severity of Test.*—(1) The average severity of the crucible method, as compared to an equal number of freezing-and-thawing cycles, is 13.2. However, it is apparent that this average should not be relied upon because of the influence of the nature of the sand upon the test, that is, the ratio of severity increases from 7.7 to 23.4 as the structure of the sand is less durable. This conclusion is generally corroborated by comparing the losses by freezing and thawing at the ultimate number of cycles with the crucible losses at 10 cycles.

(2) The average severity of the centrifuge method, as compared to an equal number of freezing-and-thawing cycles is 5.57. This average, too, is affected by the degree of durability of the material. The ratio of severity increases from 2.3 to 12.0 with a decrease in the natural soundness of the material.

(*b*) *Concordance of Results.* — (1) The mean deviation from the average loss after 10 cycles of the crucible method, for the four sand types, is 12.5 per cent with a maximum individual deviation of 45 per cent. The degree of concordance does not seem to be definitely affected by the amount of loss in the sample.

The maximum deviation from the mean loss for each grain size is greater than the deviation from the average for the sample.

(2) The mean deviation from the average loss after 10 cycles of the centrifuge method, for the four sand types, is 5.31 per cent with a maximum individual deviation of 18.8 per cent. It is worthy of especial note that the mean deviation for the sample UN-1 (Table V) is 2.5 times greater than for any of the other three and that the maximum individual deviation occurs in this sample. The geological nature of this sand is believed to be responsible for this behavior. The sand is heterogeneous and is made up of fine fragments from a multitude of schistose rocks and metamorphosed sediments, and it contains an appreciable amount of free mica.

TABLE V.—COMPARISON OF SEVERITY AND CONCORDANCE OF METHODS OF TEST OF FINE AGGREGATE DURABILITY, SAND UN-1.

Test	Individual Losses, per cent					Average of Tests, per cent	Deviation, per cent	Average Deviation, per cent	Maximum Deviation, per cent
	Grain Size, 8	Grain Size, 14	Grain Size, 28	Grain Size, 50	Average				
CRUCIBLE METHOD (10 CYCLES)									
No. 1	24.50	15.00	15.00	13.00	16.90	....	+18.20	....	....
No. 2	26.00	20.00	11.00	13.00	17.50	....	+22.40	....	....
No. 3	22.00	12.50	11.00	9.00	13.60	....	−4.90	....	....
No. 4	9.40	13.50	10.00	9.70	10.65	....	−25.20	....	....
No. 5	23.10	14.00	9.85	8.70	13.90	....	−2.80	....	....
No. 6	12.50	12.80	10.30	9.50	11.20	....	−21.60	....	....
No. 7	19.30	16.40	14.00	12.20	16.10	....	+12.60	....	....
Average	19.50	15.00	11.60	10.90	....	14.3	....	15.4	25.2
Maximum Deviation	52.00	33.00	29.00	20.00	....	....	....	....	....
CENTRIFUGE METHOD (SPEED 3 TO 10 CYCLES)									
No. 1	12.00	6.50	4.00	7.00	7.40	....	7.20	....	....
No. 2	8.20	5.60	3.60	5.00	5.60	....	18.80	....	....
No. 3	9.00	7.90	4.30	8.00	7.30	....	5.80	....	....
No. 4	7.00	4.50	5.50	6.00	5.70	....	17.40	....	....
No. 5	11.00	5.00	5.00	9.50	7.60	....	10.10	....	....
No. 6	9.50	6.00	6.50	9.00	7.70	....	11.60	....	....
No. 7	9.10	7.70	4.50	7.80	7.10	....	2.90	....	....
Average	9.40	6.20	4.80	7.50	....	6.90	....	10.50	18.80
Maximum Deviation	28.00	34.00	35.00	32.00	....	....	....	....	....
FREEZING-AND-THAWING TEST (70 CYCLES)									
No. 1	17.75	9.43	5.10	3.45	8.94	....	5.90	....	....
No. 2	15.05	11.65	....	4.70	10.47	....	10.20	....	....
No. 3	18.60	10.20	3.90	3.05	8.94	....	5.90	....	....
Average	17.13	10.43	4.50	3.73	....	9.50	....	7.30	10.20
Maximum Deviation	12.20	11.70	13.30	27.00	....	....	....	....	....

RATIO OF SEVERITY

METHOD OF TEST	LOSS	RATIO
Freezing-and-thawing	1.30	1
Centrifuge	6.90	5.30
Crucible	14.30	11.00

The maximum deviation from the mean loss for each grain size is greater than the deviation from the average for the sample, as in the crucible procedure.

(3) The mean deviation from the average loss after 70 cycles of the freezing-and-thawing procedure, for the four types of sand, is 6.3 per cent with a maximum individual deviation of 13.1 per cent. The degree of concordance did not seem to be affected as much by the nature of the sand as in the case of the sulfate methods.

(*c*) *Relationship Between Crucible and Centrifuge Methods.*—Table II contains a comparison between the average crucible and centrifuge procedures for all of the sixteen sands included in the research program. The crucible procedure averages 2.54 times the severity of the centrifuge method, but the ratio of severity varies from unity to 4.0 depending largely upon the mineral structure of the aggregate. This lack of correlation between the methods is believed to be one of the most important developments of the program because it reflects directly upon that clause of A.S.T.M. Tentative Method C 88 - 37 T which states, in part:

TABLE VI.—COMPARISON OF SEVERITY AND CONCORDANCE OF METHODS OF TEST OF FINE AGGREGATE DURABILITY, SAND FF-5.

Test	Individual Losses, per cent					Average of Tests, per cent	Deviation, per cent	Average Deviation, per cent	Maximum Deviation, per cent
	Grain Size, 8	Grain Size, 14	Grain Size, 28	Grain Size, 50	Average				
CRUCIBLE METHOD (10 CYCLES)									
No. 1	12.00	8.00	10.50	8.00	9.60	....	13.60	....	....
No. 2	9.00	12.00	9.00	6.00	9.00	....	6.50	....	....
No. 3	11.50	11.50	7.50	7.00	9.40	....	11.20	....	....
No. 4	12.00	7.50	6.50	5.00	7.75	....	8.30	....	....
No. 5	10.85	4.35	4.80	5.95	6.50	....	23.00	....	....
No. 6	11.90	8.20	10.20	7.80	9.40	....	11.20	....	....
No. 7	10.00	7.70	6.60	5.20	7.40	....	12.40	....	....
Average	11.07	8.67	7.70	6.40	....	8.45	....	12.3	23.0
Maximum Deviation	18.70	50.00	38.00	32.00	....	....	....	....	....
CENTRIFUGE METHOD (SPEED 3 TO 10 CYCLES)									
No. 1	4.0	2.0	2.0	2.0	2.5	....	2.3	....	....
No. 2	4.0	2.5	2.5	2.5	2.9	....	13.3	....	....
No. 3	4.0	2.0	1.5	2.0	2.4	....	6.2	....	....
No. 4	4.0	1.5	2.0	2.5	2.5	....	2.3	....	....
No. 5	3.0	2.0	1.7	4.0	2.5	....	2.3	....	....
No. 6	3.8	2.0	1.9	2.7	2.6	....	1.6	....	....
No. 7	3.9	1.9	1.9	2.5	2.6	....	1.6	....	....
Average	3.8	2.0	1.9	2.6	....	2.56	....	4.2	13.3
Maximum Deviation	21.0	25.0	29.0	54.0	....	....	....	....	....
FREEZING-AND-THAWING TEST (70 CYCLES)									
No. 1	5.0	3.0	1.0	1.5	2.62	....	4.7	....	....
No. 2	5.5	3.0	1.0	1.5	2.75	....	0.0	....	....
No. 3	5.5	3.5	1.0	1.5	2.97	....	4.4	....	....
Average	5.3	3.16	1.0	1.5	....	2.75	....	3.0	4.7
Maximum Deviation	5.7	10.7	0	0	....	....	....	....	....

RATIO OF SEVERITY

METHOD OF TEST	LOSS	RATIO
Freezing-and-thawing	1.1	1
Centrifuge	2.56	2.3
Crucible	8.45	7.7

Containers.—Suitable container (Note) for immersing the samples of aggregate in the solution in accordance with the procedure hereinafter described shall be selected. Containers shall be non-metallic or of metal not subject to corrosion by sodium sulfate or magnesium sulfate.

The Note mentioned in the foregoing reads as follows:

NOTE.—*No standard form of container is recommended since different practices will be most convenient in various laboratories.* The committee has had presented to it data indicating that the type of container may affect the results *in some degree*, but these data are not sufficiently comprehensive to permit of specifying a particular type . . . . [The italics are the author's.]

(*d*) *Rate of Attack.*—Figure 8 contains graphic representation of the rate of attack of the three types of test upon the four principal sands used in the research program. The freezing-and-thawing curves shown in the lower half of the figure were plotted from the average results obtained in the series represented in Tables III to VI. The centrifuge test curves were obtained from special test runs in which the samples were interrupted after each succeeding cycle so that the progressive losses could be determined. The crucible curves were

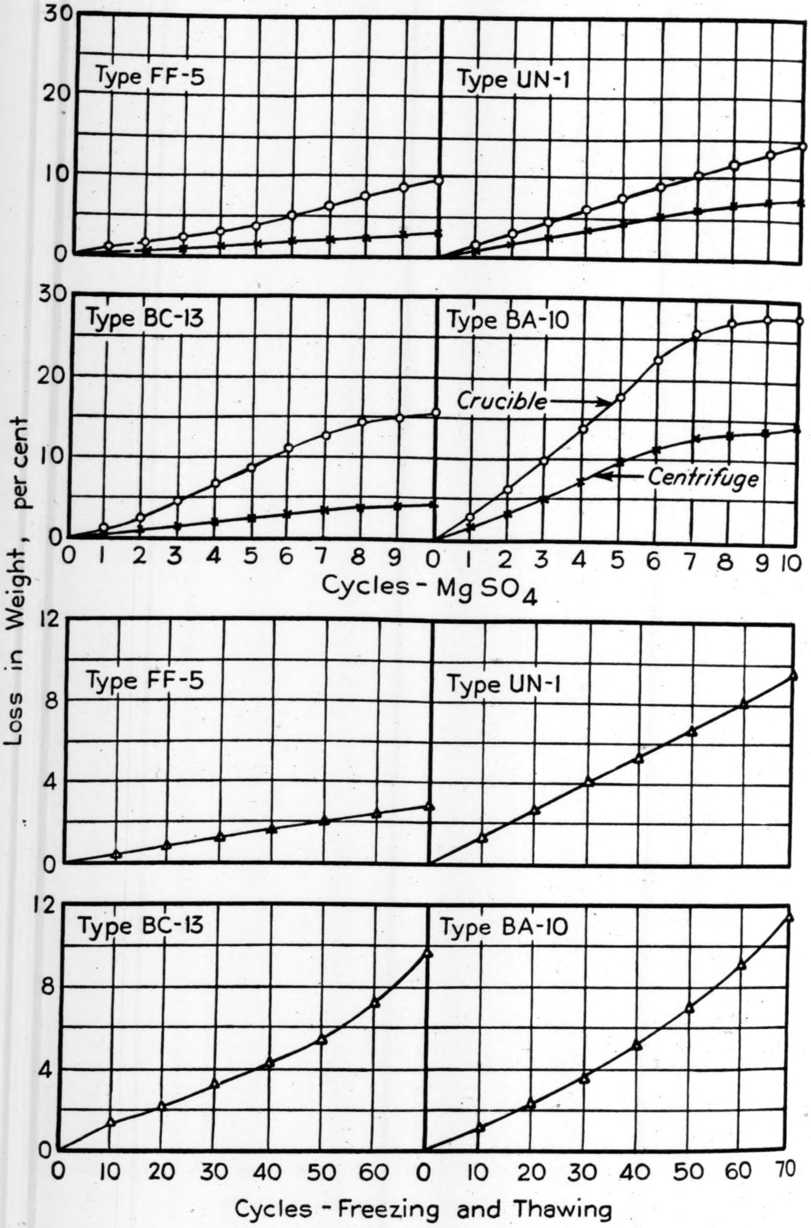

FIG. 8.—Rate of Attack by Three Types of Durability Tests. Fine aggregate.

obtained by testing four special sets of samples for each sand, that is, one set was run to 2 cycles, one to 5 cycles, one to 8 cycles, and one to 10 cycles. From these curves, it is apparent that as the type of sand becomes less durable, the rate of attack seems to be more rapid in the early stages of the sulfate test. The opposite tendency is noted as the cycles of the freezing-and-thawing test progress.

TABLE VII.—COMPARISON OF RESULTS OF FREEZING AND THAWING WITH RESULTS OF THE MAGNESIUM-SULFATE TEST OF COARSE AGGREGATE (GRAVELS).

Coarse Aggregate	Origin Type	Loss, Freezing-and-Thawing Test, per cent						Loss, Magnesium-Sulfate Test, per cent			Ratio of Increase $\frac{\text{10 cycles}}{\text{5 cycles}}$ MgSO$_4$	Ratio of Severity $\frac{\text{MgSO}_4}{\text{F \& T}}$[a]
		10 Cycles	15 Cycles	20 Cycles	25 Cycles	30 Cycles	Deviation	5 Cycles	10 Cycles	Deviation		
NO-1..........	Chert	2.0	3.0	3.8	4.3	4.5	−28.6	1.5	5.0	+25.0		
		4.7	5.8	6.6	7.9	8.6	+36.5	1.0	3.1	−22.5		
		2.7	4.0	4.8	5.4	5.8	−23.8	1.5	4.0	0		
Average.......	....	3.1	4.3	5.1	5.5	6.3	29.6	1.3	4.0	16.0	3.10	1.30
LI-1...........	Quartz	1.1	1.1	1.2	1.1	1.3	−31.5	1.2	1.75	+16.7		
		0.4	1.0	1.3	1.3	1.4	−26.3	1.0	1.25	−16.7		
		1.4	2.0	2.5	2.8	3.2	+68.3	1.0	1.40	− 6.7		
Average.......	....	1.0	1.4	1.7	1.7	1.9	42.0	1.0	1.50	13.4	1.50	1.50
HO-1..........	Vesicular Basalt	8.6	11.9	12.0	...	...	+ 0.8	6.0	10.00	−11.5		
		7.0	12.6	13.2	...	...	+10.1	8.2	14.00	+23.9		
		6.0	9.6	10.5	...	...	−11.7	5.3	9.80	−13.3		
Average.......	....	7.2	11.4	11.9	...	...	10.9	6.5	11.3	16.2	1.74	1.57
BO-1..........	Basalt	0.4	0.7	1.2	1.6	1.8	−14.3	0.6	1.5	+ 7.1		
		0.9	1.2	1.8	2.3	2.6	+23.8	0.4	1.4	0		
		0.6	0.8	1.2	2.0	2.1	0	0.5	1.4	0		
Average.......	....	0.6	0.9	1.4	2.0	2.1	16.0	0.5	1.4	2.4	2.80	2.33
FP-1..........	Sedimentary Quartzites	1.5	2.6	3.8	4.4	5.0	+ 4.2	0.7	1.2	0		
		1.8	2.0	2.6	2.9	3.3	−31.3	0.5	1.1	− 8.3		
		4.3	4.6	5.3	5.7	6.0	+25.0	0.9	1.3	+ 8.3		
Average.......	....	2.5	3.1	4.0	4.3	4.8	20.1	0.7	1.2	5.5	1.71	0.48
WA-1..........	Schist	3.9	8.0	8.9	11.9	....	+ 3.50	2.0	3.4	−39.3		
		2.6	7.3	8.9	12.0	....	+ 4.34	4.5	6.5	−16.1		
		4.4	5.1	6.5	10.5	....	− 8.20	5.0	7.0	+25.0		
Average.......	....	3.6	6.8	8.1	11.5	....	5.34	3.8	5.6	23.5	1.47	1.55
BH-2..........	Calcareous Sandstone	14.8	21.6	....	....	....	+ 2.40	11.0	15.45	−13.1		
		15.7	18.5	....	....	....	−12.30	13.3	19.90	+11.8		
		20.0	23.3	....	....	....	+10.40	13.6	18.00	+ 1.1		
Average.......	....	16.8	21.1	....	....	....	8.40	12.6	17.80	8.7	1.41	1.06
BC-28..........	Argillaceous Sandstone	18.3	27.0	....	....	....	+ 2.3	8.0	14.0	− 7.3		
		16.5	28.0	....	....	....	+ 6.1	9.8	15.3	+ 1.3		
		15.6	24.3	....	....	....	− 8.0	10.6	16.1	+ 6.6		
Average.......	....	16.8	26.4	....	....	....	5.5	9.5	15.1	5.1	1.59	0.90
BB-4..........	Argillaceous Sandstone	44.0	49.0	....	....	....	+ 3.0	25.0	33.1	+ 2.8		
		38.0	47.0	....	....	....	− 1.3	22.6	29.5	− 8.4		
		40.0	47.0	....	....	....	− 1.3	26.3	34.1	+ 5.9		
Average.......	....	40.7	47.6	....	....	....	1.5	24.6	32.2	5.7	1.31	0.79
PWS-21........	Siliceous and Granitic Gneiss	5.30	6.30	7.90	8.60	....	−29.5	8.6	17.2	+18.6		
		6.30	9.20	11.30	12.90	....	− 5.7	7.1	12.4	−14.5		
		8.25	10.40	13.80	15.10	....	+23.8	7.7	13.8	− 4.8		
Average.......	....	6.62	8.60	11.00	12.20	....	19.7	7.8	14.5	12.6	1.86	2.20
HB-3..........	Granitic	10.60	10.80	....	....	....	− 7.7	3.60	4.75	−12.0		
		11.65	12.30	....	....	....	+ 5.1	4.30	6.00	+11.1		
		11.20	12.00	....	....	....	+ 2.6	4.20	5.40	0		
Average.......	....	11.15	11.70	....	....	....	5.1	4.00	5.40	7.7	1.35	0.48
DO-1..........	Quartzitic Sandstone	11.90	13.70	....	....	....	+20.2	13.50	17.30	+ 3.9		
		8.00	8.60	....	....	....	−24.6	13.60	16.15	− 3.0		
		10.70	11.80	....	....	....	+ 3.5	12.40	16.50	− 0.9		
Average.......	....	10.20	11.40	....	....	....	16.1	13.20	16.65	2.6	1.26	1.63
				Average..........			15.0	....	....	9.9	1.76	1.32

[a] At 10 cycles.

Coarse Aggregate:

Table VII contains the tabulated results of the magnesium-sulfate and freezing-and-thawing tests conducted on the twelve types of coarse aggregate used in the program. Analysis of these data indicates the following salient features:

(*a*) *Severity of Test.*—The ratio of severity of ten cycles of the magnesium-sulfate test to an equal number of freezing-and-thawing cycles varies from 0.48 to 2.33 with an average ratio of 1.32. The range of ratios indicated seems to be influenced more by the geological nature of the coarse aggregate sample than by its relative durability.

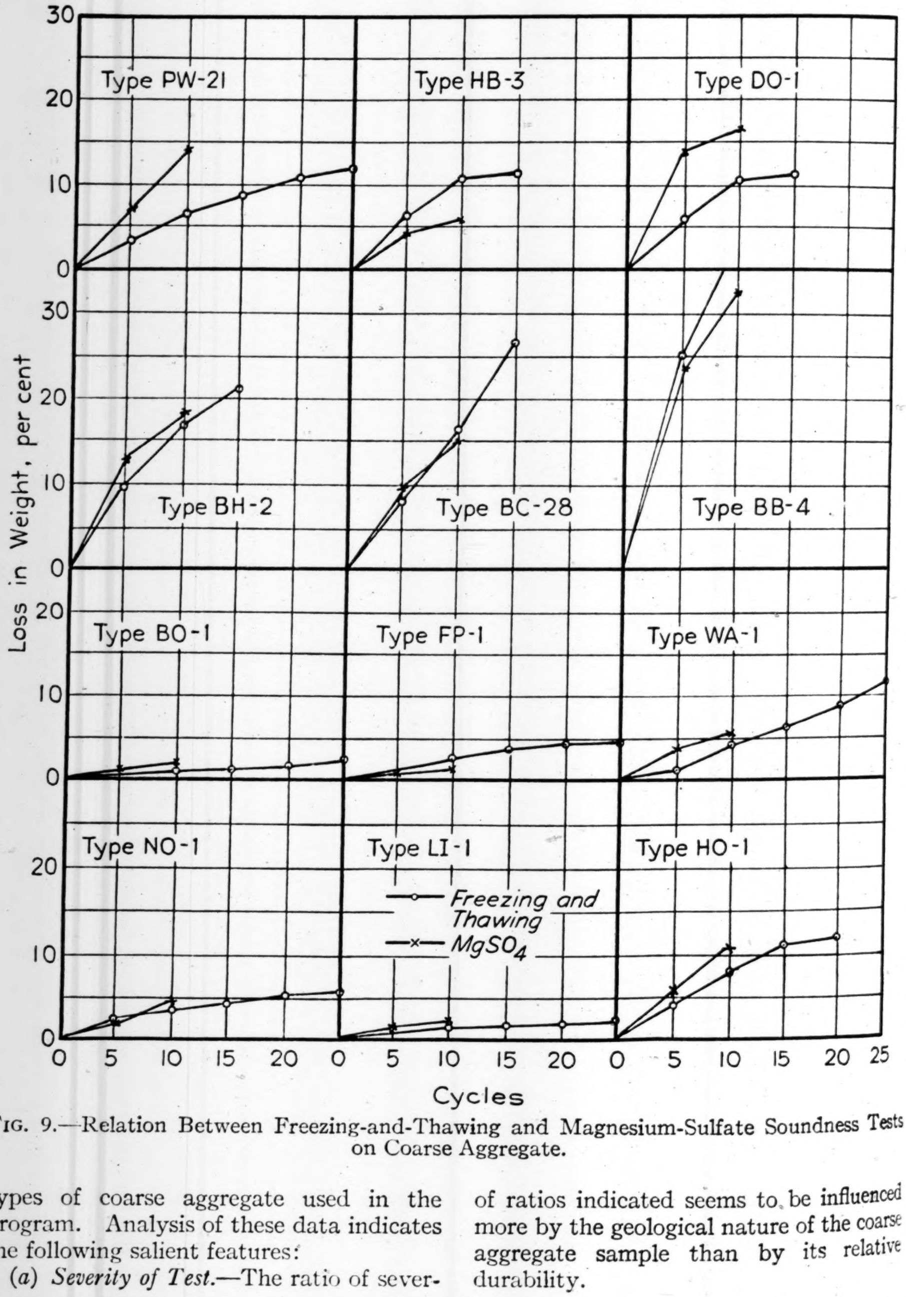

FIG. 9.—Relation Between Freezing-and-Thawing and Magnesium-Sulfate Soundness Tests on Coarse Aggregate.

The establishment of the fact that four of the twelve typical samples of coarse aggregate are attacked more rapidly by laboratory freezing and thawing than by the magnesium-sulfate test was surprising. Only slightly less surprising and of equal importance, was the development that the magnesium-sulfate test averaged only 1⅓ times as severe as freezing and thawing when testing coarse aggregate.

(*b*) *Rate of Attack.*—The general similarity in rate and extent of attack between the two types of test is illustrated in the twelve graphs in Fig. 9. The rate of attack in the sulfate test is expressed numerically in Table VII as the ratio of increase from 5 to 10 cycles. This latter ratio varies from 1.26 to 3.10 with an average of 1.76 for the twelve types of coarse aggregate.

TABLE VIII.—RELATION BETWEEN UNCONFINED TESTS OF COARSE AGGREGATE AND FREEZING AND THAWING OF CONCRETE.

Type	Cycles of Freezing and Thawing						Loss at 10 Cycles, per cent	
	20 per cent Weight Loss		0.40 per cent Expansion		Complete Failure			
	Wet	Dry	Wet	Dry	Wet	Dry	Freezing and Thawing	$MgSO_4$
BO-1	85	98	90	98	94	98	0.6	1.4
LI-1	85	135	81	96	90	140	1.0	1.5
FP-1	75	95[a]	75	80	78	95	2.5	1.2
NO-1	70	75	70	68	82	83	3.1	4.0
HO-1	68	140	95[b]	130	95	155	7.2	11.3
DO-1	67[a]	74[a]	67	74[a]	67	74	10.2	16.6
HB-1	60	70[a]	52	63	62	70	11.5	5.4
BC-28	50	..	49	..	55	..	16.8	15.6

[a] Complete failure prior to 20 per cent loss or 0.40 per cent expansion.
[b] Failed at 0.15 per cent expansion.

(*c*) *Concordance of Results.*—The concordance of results in the sulfate test and freezing-and-thawing test is expressed in Table VII as the individual and average deviation from the mean losses for each type and for the twelve types as a whole. The total average deviation in the magnesium-sulfate procedure is 9.9 per cent as compared with 15 per cent in the freezing-and-thawing test. The magnesium-sulfate results were also more concordant within each type than were the freezing-and-thawing results.

Concrete:

Table VIII contains a tabulation of the comparative data compiled from the freezing and thawing of 45 concrete beams containing 8 of the types of coarse aggregate tested in the program. Figures 10, 11, 12, and 13 illustrate graphically the rate of attack on typical groups in terms of inelastic length increase and weight loss; and also, in the case of the latter two, the degree of concordance obtained between individual specimens of a group.

Figure 14 is a photograph of two beams after 25 cycles of freezing and thawing. The failure of the thinly laminated pebbles of finely grained sandstone is evident. Figure 15 shows a close-up view of the effect of an unsound gravel pebble upon the surrounding concrete. Subsequent cycles of freezing and thawing of this specimen finally resulted in the splitting of the specimen in two parts with this one pebble being responsible for the failure.

The data in Table VIII are arranged in the increasing order of loss by freezing and thawing the unconfined coarse aggregate. While the disintegration of the constantly immersed concrete generally follows the trend indicated by the two unconfined aggregate tests, it is apparent that the mortar surrounding the coarse aggregate served to protect the poor material to a certain extent and, conversely, that the mortar itself had only a limited resistance to the frost action.

There appears to be a more rational relation between 20 per cent loss by weight

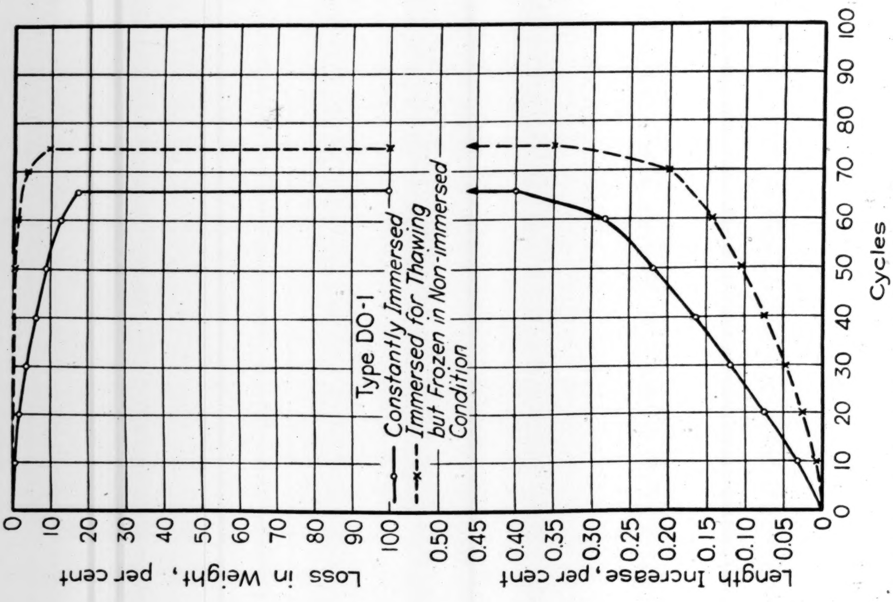

FIG. 11.—Inelastic Length Increase as Compared with Weight Loss in the Freezing and Thawing of Concrete.

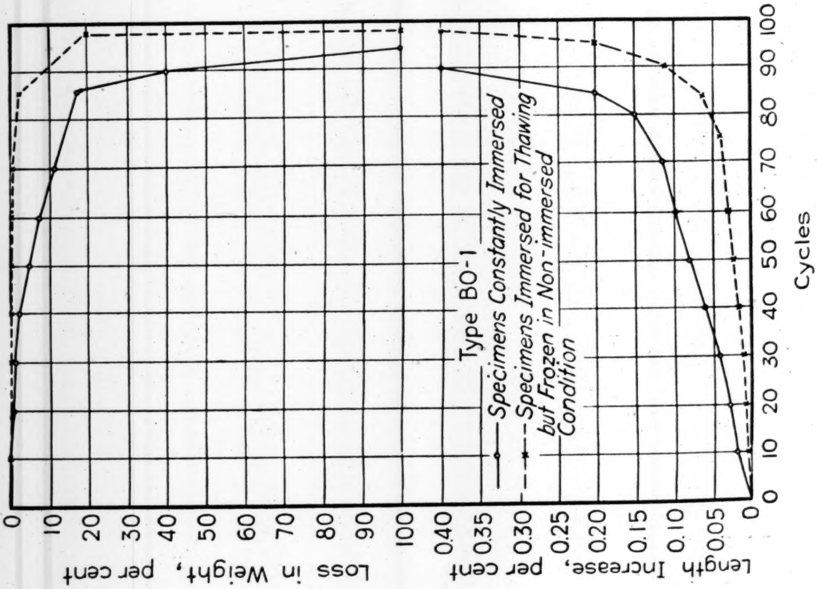

FIG. 10.—Inelastic Length Increase as Compared with Weight Loss in the Freezing and Thawing of Concrete.

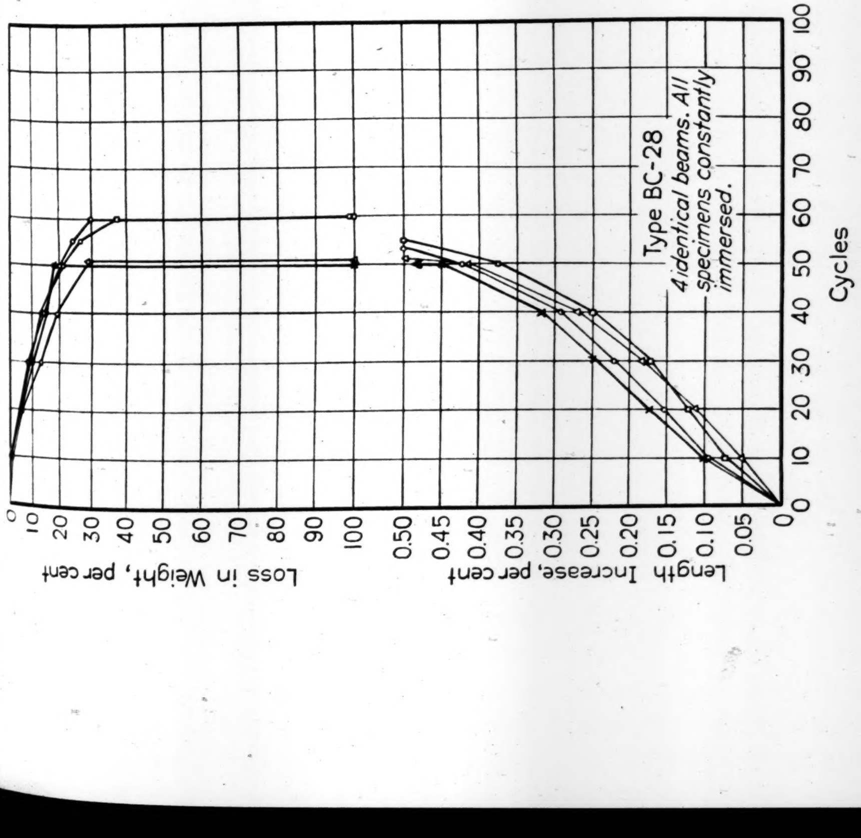

FIG. 12.—Inelastic Length Increase as Compared with Weight Loss in the Freezing and Thawing of Concrete—Concordance of Results.

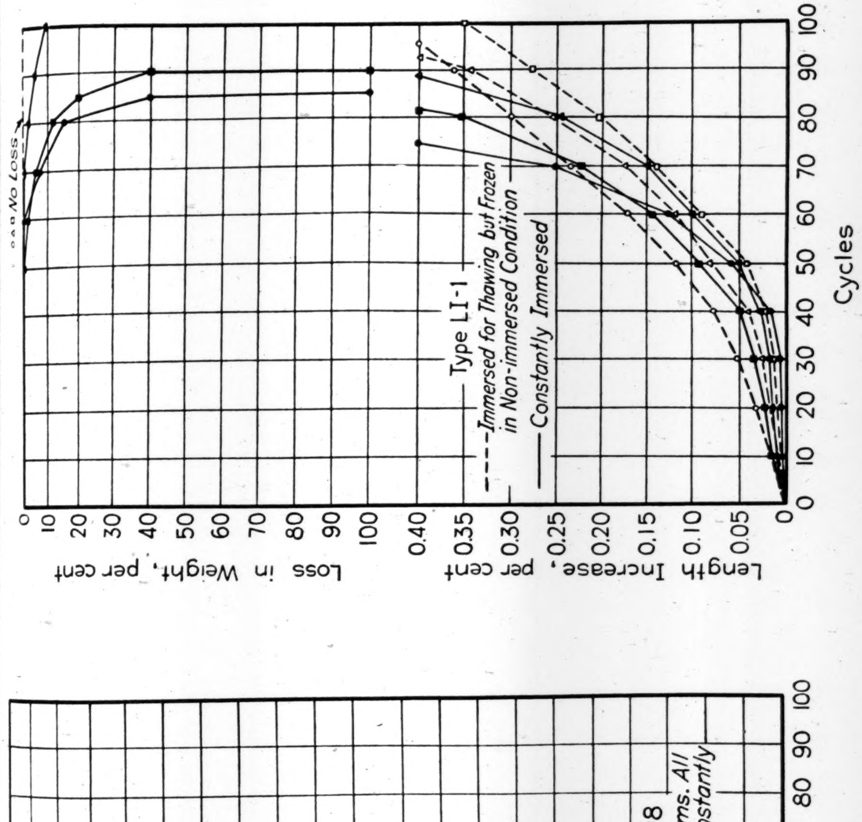

FIG. 13.—Inelastic Length Increase as Compared with Weight Loss in the Freezing and Thawing of Concrete—Concordance of Results.

FIG. 14.—Freezing and Thawing. Concrete beams. Showing coarse aggregate failure at 25 cycles.

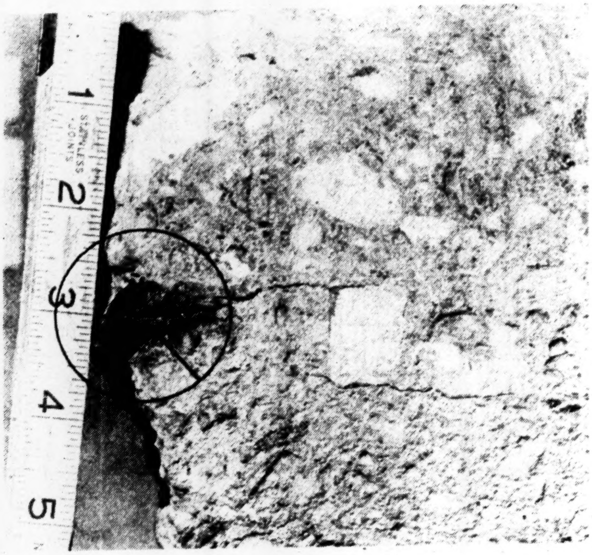
1
2
3
4
5
STAINLESS JOINTS

FIG. 15.—Splitting of Concrete by Failure of One Coarse Aggregate Particle.

and 0.40 per cent increase in length, of the constantly immersed specimens, as criteria of durability than complete failure of the specimen. During the progress of the test, it was observed that after a specimen had lost 20 per cent of its weight or expanded 0.40 per cent in length, the entire specimen had been seriously attacked and could be demolished by picking apart with very little effort.

The manner in which the specimen is exposed to frost appears to have less effect upon its inelastic expansion than upon its loss in weight. In every case where the specimens were frozen in a saturated but non-immersed condition, their loss in weight lagged appreciably behind the weight loss in specimens frozen in an immersed condition, although complete failure of the "dry" specimens usually occurred in only a few additional cycles. In general, the "dry" specimens were more inconsistent than the constantly immersed specimens.

TABLE IX.—PHYSICAL AND CHEMICAL PROPERTIES OF THE HYDRATES OF MAGNESIUM SULFATE AS RELATED TO THE SULFATE TEST.

PART A[a]

SOLUBILITY OF $MgSO_4 \cdot 7H_2O$ IN WATER

TEMPERATURE, DEG. CENT.	$MgSO_4$, PER CENT
2	20.9
2	20.9
7	22.5
23	26.0
67	35.6
81	38.6
94	41.5
130	43.3

PART B[a]

SPECIFIC GRAVITY OF $MgSO_4$ AND ITS HYDRATES

FORMULA	d_4^{20}
$MgSO_4$	2.66
$MgSO_4 \cdot H_2O$	2.57
$MgSO_4 \cdot 5H_2O$	1.71
$MgSO_4 \cdot 6H_2O$	1.76
$MgSO_4 \cdot 7H_2O$	1.68

PART C[a]

TRANSITION TEMPERATURES OF HYDRATES OF $MgSO_4$ WHEN PRECIPITATED FROM SOLUTION

$MgSO_4 \cdot 7H_2O \longrightarrow MgSO_4 \cdot 6H_2O$		48.2 C.
$MgSO_4 \cdot 6H_2O \longrightarrow MgSO_4 \cdot H_2O$		68 C.

PART D[b]

DEHYDRATION OF METALLIC SULFATES

METALLIC SULFATE	TEMPERATURE AT WHICH DECOMPOSITION COMMENCES, DEG. CENT.
$MgSO_4 \cdot 7H_2O$	19
$MgSO_4 \cdot 6H_2O$	38
$MgSO_4 \cdot 2H_2O$	112
$MgSO_4 \cdot H_2O$	203

[a] International Critical Tables.

[b] Handbook of Chemistry and Physics.

PHYSIO-CHEMICAL REACTIONS OF MAGNESIUM SULFATE

The preceding portion of this paper has been principally devoted to a discussion of the physical effects of magnesium-sulfate solution upon concrete aggregate. The ensuing paragraphs are devoted to the development of an hypothesis of what the physio-chemical action of the solution and its dehydrated and hydrated crystalline salts is when exposed to the thermal influences of the procedure.

The disintegrating action of frost in concrete or natural rocks is assumed to be due to the 9 per cent increase in volume coincident with the transformation of water into ice. If the magnesium-sulfate test is actually an *accelerated* soundness test and is only physical in its action, it is logical to assume that the cubical expansion of the magnesium sulfate is greater than in the formation of ice.

The solution used in the sulfate test is prepared by dissolving one part of $MgSO_4 \cdot 7H_2O$ in one part of water by weight. Such a solution is *saturated* with respect to $MgSO_4 \cdot 7H_2O$ at 57 F. By preparing the solution in this manner, it is possible to permit the variation of the solution temperature from 55 to 70 F. without altering its concentration.

The concentration is maintained constant, from day to day, by addition of water or crystalline sulfate as indicated by hydrometer readings (specific gravity (d_4^{20}) 1.275). This maintenance of concentration constancy is essential to the accuracy of results.

The immersion of dehydrated aggregate samples in the magnesium-sulfate solution for a period of 17 or 18 hr. has been described. During this time the pores and interstices of each particle become filled with the sulfate solution. Then, during the drying cycle, the aggregate is exposed to a temperature of 105 C. (220 F.) for 6 hr. During this time $MgSO_4 \cdot H_2O$ crystallizes from solution within the aggregate particles. That $MgSO_4 \cdot H_2O$ does precipitate under these conditions may be seen by observing parts C and D in Table IX. $MgSO_4 \cdot H_2O$ crystallizes from solution above 67 C. (152 F.) and will not decompose at temperatures less than 203 C. (395 F.).

Upon reimmersion, the $MgSO_4 \cdot H_2O$ within the aggregate particles becomes hydrated and expands. The exact hydrate formed under these conditions has not been determined with certainty. If $MgSO_4 \cdot 2H_2O$ is formed, there will be an expansion of about 23.0 per cent. If $MgSO_4 \cdot 5H_2O$ is formed, the expansion will be 128 per cent and if $MgSO_4 \cdot 7H_2O$ is formed, the expansion will be 172 per cent. The derivation of the above is given in Table X.

TABLE X.—THEORETICAL WEIGHT AND VOLUME CHANGES UNDERGONE BY $MgSO_4 \cdot H_2O$ UPON HYDRATION TO THE $MgSO_4 \cdot 2H_2O$, $MgSO_4 \cdot 5H_2O$ AND $MgSO_4 \cdot 7H_2O$ STAGES, RESPECTIVELY.

Hydrates	Specific Gravity	Weight of Salt Derived from 2.57 g. $MgSO_4 \cdot H_2O$ After Hydration, g.	Volume of Salt Derived from 1 ml. (2.57 g.) $MgSO_4 \cdot H_2O$ After Hydration, cu. cm.	Increase in Volume After Hydration of $MgSO_4 \cdot H_2O$, per cent
$MgSO_4 \cdot H_2O$	2.57	....	....	...
$MgSO_4 \cdot 2H_2O$	2.36[a]	2.90	1.23	23
$MgSO_4 \cdot 5H_2O$	1.718	3.91	2.28	128
$MgSO_4 \cdot 7H_2O$	1.68	4.58	2.72	172

[a] Interpolated.

The author believes that it is the expansive force of the formation of one of the above hydrates *during the immersion period* which causes the disintegrating action within the aggregate particles. During successive cycles, the expansive force is repeated and a fatigue stress similar in quality but greater in quantity to freezing and thawing is set up.

The following properties of magnesium-sulfate monohydrate ($MgSO_4 \cdot H_2O$) were taken from authoritative treatises on chemistry:

"$MgSO_4 \cdot H_2O$ can be obtained by heating the heptahydrate to 130 to 140 C. The crystals do not lose their water at 100 C. and when heated to higher temperatures they fly to pieces without melting. When kept in moist air, the crystals become opaque, take up a mole of water *and set like a cement.* [These italics are the author's.] Under water, the crystals, likewise, set to a cement-like mass which dissolves in water as the heptahydrate."[5]

"The monohydrate will also separate from solutions of magnesium sulfate at temperatures above 67 C."[6]

The foregoing does much to explain the action of the test—especially the caking of the excess solution in the crucible procedure.

CONCLUSIONS

The conclusions, which the author feels may be drawn from the test program, are as follows:

1. The magnesium-sulfate accelerated soundness test of either fine or coarse aggregate bears no constant relation to the freezing-and-thawing test.[7] In spite of the lack of this relationship, the magnesium-sulfate test is a desirable one, if properly conducted. This conclusion arises from the economy of the test as compared to freezing and thawing and, in the case of fine aggregate, a pronounced acceleration of results.

2. Freezing and thawing of unconfined aggregate affords no truer prediction of the action of the aggregate when confined in

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[5] Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry," Longmans, Green and Co., London, England (1922).

[6] M. S. Burr, "Textbook of Inorganic Chemistry," Vol. III, Part II, p. 62, Charles Griffin and Co., Ltd., London, England (1924).

[7] By the freezing-and-thawing method described herein.

concrete than does the magnesium-sulfate test.

3. Assumption may be made that the magnesium-sulfate test of fine aggregate (centrifuge method) is about five times as severe as the freezing-and-thawing test.[7]

4. (*a*) The magnesium-sulfate test of coarse aggregate may be assumed to be little more severe than the freezing-and-thawing test,[7] and, because of this conclusion, the requirements for acceptance based upon the magnesium-sulfate test should be increased from the generally prevalent 10 to 15 per cent loss after 5 cycles for aggregate which will enter concrete exposed to severe climatic attack. In this connection, it is not believed safe to permit the use of coarse aggregate, in such concrete, which develops a loss in excess of 10 per cent after 10 cycles of the test.

5. It is considered definitely desirable to amend the A.S.T.M. Tentative Method C 88 - 37 T to provide for the use of a standard container at least for fine aggregates *and* an adequate procedure for the removal of surplus solution from the sample prior to drying. In this connection, it is believed that wire-mesh baskets spun in a centrifuge constitute the most satisfactory practice.

6. Close control of solution temperature has not been found to be essential to the accuracy of the magnesium-sulfate test, providing the concentration of the solution is constantly maintained. The requirement for close temperature control specified in Section 6 of C 88 - 37 T is believed unnecessary and inimical to the general adoption of the test. Very few laboratories have the space in constant temperature rooms for the conduct of numerous sulfate tests. If this control is necessary when sodium sulfate is used, this compound should be subordinated in favor of the more stable magnesium sulfate.

7. Testing of an aggregate by freezing and thawing concrete specimens containing it, with weight loss as criterion, presents difficulties originating in the effect of frost upon the mortar and the type of failure of the aggregate; that is, there may be a gradual deterioration or a sudden disruption depending upon the nature of the aggregate. This condition would make the establishment of acceptance standards on a quantitative basis exceedingly difficult.

8. In the final analysis, the tests are simply relative and bear no fixed relation to the natural attack upon a concrete mass. There is no formula known to the author for translating laboratory cycles of freezing and thawing of concrete or concrete aggregate into the freezing cycles of nature.

The freezing-and-thawing test and the sulfate test both expose the structural weaknesses in aggregate particles; therefore, the problem should be attacked from a standpoint of readily usable standards for either test rather than *which* test to use.

DISCUSSION

MR. C. H. SCHOLER.[1]—I wish to compliment Mr. Wuerpel on the discussion of the sodium sulfate test which he so ably presented. I have long thought that this salt has such a peculiar solubility curve that we could not have found a more unsatisfactory material with which to work. I do not agree with Mr. Wuerpel that the cost of making actual freezing-and-thawing tests of aggregate or concrete is sufficient to justify the retention of the sodium sulfate or the magnesium-sulfate test. A rather ridiculous attitude is taken in the field of concrete when we feel perfectly justified in buying a \$6000 compression testing machine but cannot spend one-fourth as much on apparatus with which to study durability. When we know the properties of our cement, have selected our aggregate, determined the water-cement ratio, and given proper curing, the last thing in the world we expect is trouble with the compressive strength of our concrete; yet we will spend thousands of dollars for a testing machine with which to confirm our judgment. The all-important question of durability is given little attention other than a mild dose of wishful thinking. I hope Mr. Wuerpel's paper may stir up a little more interest in this subject and perhaps we will be more willing to spend some time and money to learn of those things which we do not understand.

MR. THADDEUS MERRIMAN.[2]—It may be interesting to note briefly that possibly the use of potassium sulfate instead of the other two salts might give better results, for the reason that potassium sulfate crystallizes without water hydration. Possibly Mr. Wuerpel is in a position to comment on this.

MR. CHARLES E. WUERPEL[3] (*author's closure by letter*).—The discussion of sodium sulfate referred to by Mr. Scholer was presented as an oral appendix and is not covered in the printed text. Although no tests were made with sodium sulfate in the program, it might be well to make clear the disparity which exists between it and magnesium sulfate in this closure.

The accompanying Fig. 1 gives the water-solubility curves for the two salts. The data contained in the figure indicate the following:

1. Anhydrous sodium sulfate changes to the decahydrate when introduced into water having a temperature lower than 90 F.

2. The solubility of the decahydrate of sodium sulfate is affected by temperature to a much greater extent than is the solubility of magnesium sulfate.

3. A saturated solution of magnesium sulfate at 60 F., contains 2.7 times as much salt as a saturated solution of sodium sulfate, while at 81 F. the weights of salt are equal in both solutions. This divergence would radically affect the relative results on an aggregate sample if the temperature was permitted to fluctuate in this common laboratory range. Or, expressed another way, the weight of salt required for a saturated solution of sodium sulfate is *tripled* as the temperature ranges from 60 to 81 F., whereas the weight of salt required for a saturated solution of magnesium sulfate increases by only 26 per cent, in the same temperature range.

4. With magnesium sulfate, it is practicable to establish the minimum temperature likely to occur in a laboratory; prepare a saturated solution based on that temperature and simply maintain that *degree* of

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[1] Professor of Applied Mechanics, Kansas State College of Agriculture, Road Materials Laboratory, Manhattan, Kans.

[2] Consulting Engineer, Board of Water Supply, City of New York, New York City.

[3] Engineer in Charge, Central Concrete Laboratory, U. S. Military Academy, West Point, N. Y.

concentration (specific gravity), irrespective of reasonable temperature increases, without measurably affecting the test. The high solubility of magnesium sulfate makes possible the establishment of this minimum as low as 57 F., and still have a high solid content; whereas if this were done with sodium sulfate the solid content would be extremely low, and at 70 F. less than half the solids required for saturation at this temperature would be present in the solution.

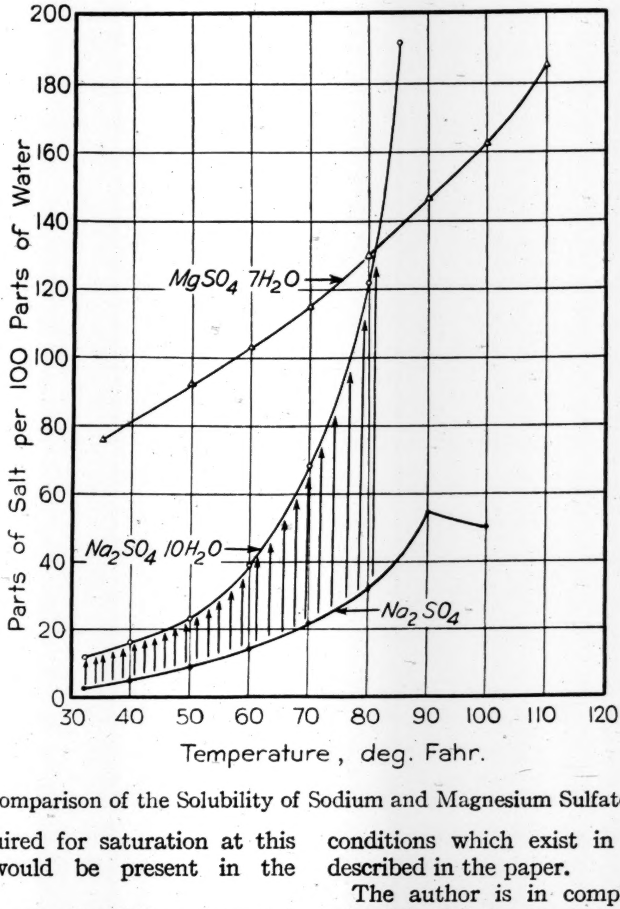

FIG. 1.—Comparison of the Solubility of Sodium and Magnesium Sulfate in Water.

5. The greater severity of the accelerated soundness test with magnesium sulfate is probably attributable to the relative amounts of solids present in saturated solutions at equal temperatures.

The author believes that the extreme sensitivity of sodium sulfate to temperature warrants its elimination from the general soundness test procedure.

Subsequent to the submittal of the paper, the question of the chemical reaction of magnesium sulfate with calcareous materials has arisen. This matter has been carefully studied, and, without going into great detail, it may be stated that the reaction is insignificant under the thermal conditions which exist in the procedure described in the paper.

The author is in complete agreement with Mr. Scholer that the importance of compressive strength is ridiculously overemphasized, but until we are able to provide a rule-of-thumb yardstick for durability which will subordinate compressive strength in the minds of the engineer and contractor, we are stuck with the compression test.

REPORT OF COMMITTEE C-11
ON
GYPSUM

Committee C-11 on Gypsum has held one meeting during the past year, at the National Bureau of Standards in Washington, D. C., on November 18, 1937. At this meeting the committee received reports from Subcommittees II on Gypsum Plasters and IV on Testing Methods, which subcommittees had been working for the past several years on a number of investigations affecting standards.

It is with a deep feeling of regret that Committee C-11 records the death of Mr. J. W. Ginder, Superintendent of Architectural Engineering, Procurement Division, Public Works Branch, who passed away on July 16, 1937. Mr. Ginder was elected chairman of Committee C-11 at the June, 1926, meeting and had served the committee in that capacity since that time. Mr. L. S. Wells was elected chairman at the November meeting to fill Mr. Ginder's unexpired term.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Gypsum for Various Uses (H. J. Brown, chairman).—At the November meeting, Mr. R. S. Edwards, a member of Subcommittee I, gave a very interesting illustrated talk on the new hydraulic gypsum cement patented by him, U. S. Patent No. 2,090,625.

Subcommittee II on Gypsum Plasters (J. M. Porter, chairman) and *Subcommittee IV on Testing Methods* (C. K. Roos, chairman).—These two subcommittees have been working together for several years doing investigative work on Keene's cement and on gypsum plasters, neat and sanded. These studies included considerations of tensile strength, fineness, testing consistency, and methods of test. Based on this investigative work, these subcommittees have recommended a number of changes in several standards, as indicated below.

RECOMMENDATIONS AFFECTING STANDARDS

Tentative Revision of Standards:

Standard Specifications for Keene's Cement (C 61 – 30).[1]—These A.S.T.M. specifications differ from the Federal Specifications for Keene's Cement (SS-C-161) in several requirements, particularly as to tensile strength, fineness and testing consistency. Considerable investigative work has been done by Messrs. J. C. Best, C. K. Roos, and L. S. Wells, to bring the two specifications into agreement.

A Keene's cement mixture made at the present so-called testing consistency is so heavy and stiff that casting of satisfactory briquets for the tensile strength determination is difficult. Also, uniform mixing of the Keene's cement with water to produce pats for determining the time of setting and the testing consistency, or briquets for the strength test is difficult. Using a 150-g. modified Vicat needle as called for in the Federal specifications in place of the 350-g. needle required under the present A.S.T.M. specifications will produce more uniform briquets and provide a more uniform series of test results. A revision in

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 81.

Section 8 of Specifications C 61 is accordingly being recommended to require that the weight of the needle be reduced from 350 g. to 150 g.

To make allowance for the increase in consistency obtained by testing Keene's cement using the lighter weight needle, it is recommended that the minimum tensile strength requirement in Section 3 be changed from "450" to "400" lb. per sq. in.

The tentative revisions in these specifications recommended by the committee are appended hereto.[1]

Standard Specifications for Gypsum Plasters (*C 28 – 30*).[2]—The tensile strength of neat gypsum plaster as prescribed in Section 8 of these specifications has been before the committee for quite a few years and numerous reports have been submitted by most of the producers. The present specifications require the plaster to be tested neat, whereas in practice it is not used neat, but with the addition of two or three parts of sand. Slow-setting neat-plaster briquets made as now specified without sand are very liable to dry out or shrink-crack before setting so that the results obtained may be much lower than the true strength of the plaster.

TABLE I.—ANALYSIS OF LETTER BALLOT RESULTS.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. TENTATIVE REVISION OF STANDARDS			
Specifications for Keene's Cement (C 61 – 30)	15	0	4
Specifications for Gypsum Plasters (C 28 – 30)	16	1	2
Methods of Testing Gypsum and Gypsum Products (C 26 – 33)	17	0	2
II. WITHDRAWAL OF STANDARD			
Specifications for Calcined Gypsum (C 23 – 30)	15	0	4

A minimum time of setting of 8 hr. is required for gypsum neat plaster under Section 7 of the present specifications. To permit the use of the new type of set-stabilized plasters now on the market and which are not influenced greatly as to setting time by job conditions, the committee recommends that the time of setting be reduced from 8 hr. to 2 hr.

The tentative revisions in these specifications recommended by the committee are appended hereto.[3]

Standard Methods of Testing Gypsum and Gypsum Products (*C 26 – 33*).[4]—To differentiate between testing technique employed for the determination of time of setting and tensile strength of unretarded plasters, plasters compounded as ready for use, and gypsum neat plasters, the committee recommends for publication as tentative the revisions in these methods appended hereto.[5]

Since 1930 Committee C-11 has been working on the ammonium acetate method of determining the sand content of set gypsum plaster and it is believed that sufficient information and technique have now been developed to propose the incorporation of this procedure in Standard Methods C 26.

The tentative revisions in these methods recommended by the committee are appended hereto.[5]

Withdrawal of Standard:

Standard Specifications for Calcined Gypsum (*C 23 – 30*).[4]—The committee has long considered discontinuing these specifications. They list two types of material: No. 1 is calcined gypsum intended for finishing-coat work and is provided for in Sections 13 to 16 of the Standard Specifications for Gypsum Plasters (C 28 – 30), whereas there is no use for No. 2 type or size. The committee, therefore, recommends that these specifications be withdrawn.

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[1] See p. 1321.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 89.

[3] See p. 1322.

[4] 1936 Book of A.S.T.M. Standards, Part II, p. 106, 76.

[5] See p. 1322.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 22 members; 19 members returned their ballots, the results being shown in Table I.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 22 members; 19 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

L. S. WELLS,
Chairman.

H. J. SCHWEIM,
Secretary.

REPORT OF COMMITTEE C-13

ON

CONCRETE PIPE

Committee C-13 on Concrete Pipe held one meeting during the year, in Chicago, Ill., on May 2, 1938.

Recommendations Affecting Standards:

Revision of Tentative Standard.—The committee recommends that the Tentative Specifications for Concrete Irrigation Pipe (C 118 - 35 T)[1] be revised, as appended hereto,[2] and continued as tentative. The revisions, which are extensive, have been made as a result of comments and criticisms received from a number of engineers conversant with irrigation practice.

This recommendation has been submitted to letter ballot of the committee which consists of 27 members; 25 members returned their ballots, of whom 23 have voted affirmatively, 0 negatively, and 2 members marked their ballots "not voting."

Withdrawal of Tentative Revision of Standard.—The following revision of the Standard Specifications for Concrete Sewer Pipe (C 14 - 35)[3] has been published as tentative since 1924:

Section 1.—Add the following footnote:

Caution.—The consumer or purchaser is cautioned against using cement-concrete pipe where the sewage shows an acid reaction.

The committee recommends the withdrawal of this tentative revision.

This recommendation has been submitted to letter ballot of the committee which consists of 27 members; 25 members returned their ballots, of whom 20 have voted affirmatively, 2 negatively, and 3 members marked their ballots "not voting."

The election of officers for the ensuing term of two years resulted in the selection of Theodore Doll as chairman and the re-election of the present vice-chairman and secretary.

This report has been submitted to letter ballot of the committee which consists of 27 members; 25 members returned their ballots, of whom 23 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

E. F. Kelley,
Chairman.

M. W. Loving,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 812 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 573.

[2] See p. 796.

[3] 1936 Book of A.S.T.M. Standards, Part II, p. 285.

REPORT OF COMMITTEE C-14
ON
GLASS AND GLASS PRODUCTS

Committee C-14 on Glass and Glass Products was organized at a meeting in New York City on June 30, 1937, following authorization by the Executive Committee of the Society resulting from a proposal by the American Ceramic Society that an A.S.T.M. committee be organized to develop American standards pertaining to glass and glass products and to act as a channel of American participation in international standardization activities pertaining to glass. A further meeting of the committee was held in Rochester, N. Y., on March 8, 1938. At these meetings of the committee consideration was given to formulating a program of work and to the organizing of six subcommittees, the names of which are given below together with a brief summary of projects to be considered or which are now under way.

The following statement of the scope of the committee has been adopted:

Scope.—The development of nomenclature and methods of analysis and testing of glass both as such and as specific products.

The present membership of the committee is 33, of whom 10 are classified as producers, 12 as consumers, and 11 as general interests.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Nomenclature and Definitions (F. C. Flint, chairman).—This subcommittee will give consideration to questions dealing with proper nomenclature and terminology and the standardization of definitions.

Subcommittee II on Chemical Analysis (G. E. F. Lundell, chairman).—This subcommittee has under way the following two projects: (*1*) the formulation of a standard method for the chemical analysis of glass sand, and (*2*) the formulation of methods for the chemical analysis of glass. A draft of the first method has been prepared and forwarded to the members of the committee for comment.

Work on the second project is proceeding in cooperation with a subcommittee appointed by the Glass Division of the American Ceramic Society, and it is hoped that considerable progress will have been made by September 1, 1938. Arrangements have been made for procuring a sample of glass. This will be used in a study of umpire and routine methods of analysis for the purpose of: (*a*) agreeing on a standard method for umpire analysis, (*b*) calling attention to the recent developments along the line of rapid routine methods, and (*c*) preparing a standard sample which will be available to those who wish to check their analyses.

Subcommittee III on Chemical Properties (D. E. Sharp, chairman).—This subcommittee is undertaking a cooperative test program similar to that conducted a few years ago by the Glass Division of the American Ceramic Society, but including the following:

1. The correlation of data obtained by the various cooperating laboratories for which arrangements have been made with G. E. F. Lundell of the National Bureau of Standards.

2. Obtain three or four additional container durability samples to add to those already in the hands of Mr. Lundell.

3. Repeat the tests by the tentative A.C.S. method No. 1 on old samples, and

run tests on new samples, using: (*a*) 0.02 *N* sulfuric acid (as before), (*b*) 0.02 *N* sodium hydroxide, and (*c*) water.

4. Run high-temperature test by a modification of the Flint-Lyle methods, on each of the containers, using: (*a*) water, (*b*) 0.02 *N* sulfuric acid, and (*c*) 0.02 *N* sodium hydroxide.

5. Run tests similar to the above, using water only, at various pressures and for various times. If previous results indicate valuable data would be obtained, run these tests also with acid and alkali.

6. Modify the Flint-Lyle method for use on sheet glass, employing either platinum or silica dishes as containers.

Subcommittee IV on Physical and Mechanical Properties (J. T. Littleton, chairman).—This subcommittee is giving consideration to tests for mechanical strength and thermal resistance.

Mr. James Bailey is in charge of the work on mechanical strength. He has submitted a draft of a method of measuring the modulus of rupture of glass, which is a proposed set of specifications for apparatus and methods for measuring the tensile strength of glass in rod and in sheet form. This draft has been circulated to the other laboratories who have been cooperating in this work with the request that they check the proposed method in detail.

The work on thermal resistance is in charge of S. R. Scholes who has developed and tested a method for making such measurements. The proposed procedure is essentially the same as that being discussed by the British Society of Glass Technology except that it differs in the length of the rod and specifications for the test sample. It is planned to have Mr. Scholes make a comparison of these two methods and report back at the summer meeting of the American Ceramic Society the results of his tests.

Subcommittee V on Thermal Properties (E. W. Tillotson, chairman).—The activities of this subcommittee have consisted largely of discussions of the significance of the thermal properties (thermal conductivity and specific heat) of glass, but no definite program as yet has been adopted.

Subcommittee VI on Glass Construction Block and Tile (J. P. Staples, chairman).—It has been decided to postpone any consideration of glass tile and to devote attention only to glass blocks for the present.

The Owens-Illinois Glass Co. in collaboration with Purdue University and in its own laboratories, has for the past two years been conducting exhaustive investigations on glass block design and performance.

Studies are likewise being made in laboratories at Corning, N. Y., Creighton, Pittsburgh, and Charleroi, Pa., and services of several outside laboratories including the Pittsburgh Testing Laboratory, University of Minnesota, and Mellon Institute of Industrial Research, are also being utilized.

Mr. A. N. Finn at the National Bureau of Standards has under way an independent investigation of glass block performance.

These three programs constitute the total of work now being done. Primarily, of course, the work is being done by the manufacturers for general development purposes. The Bureau is doing its work for the Federal Government. However, it was decided at the first meeting of the committee that the results of all of this work would be available as a foundation for any specifications that the committee might ultimately write.

This subcommittee is limiting its considerations to the physical and other characteristics of individual blocks and is not supposed to concern itself with cement mortars, methods of construction and performance of glass masonry panels. However, it has been generally agreed that the complete story must be developed before it will be possible to indicate with any assurance just what the requirements are for the blocks as units.

The work under way embraces almost conceivable sort of inquiry. Tests are being made on strength of individual blocks and of built-up panels under all conditions of loading. Attention is being focused on the strains which develop within a glass block panel due to weathering conditions. Accelerated weathering tests on full-scale installations have been carried on for many months. Photoelastic measurements have been and are being made on full-sized panels under service conditions.

Investigations have been made on light transmission, heat transmission, sound transmission, and the effects of solar radiation.

More than two years' work has gone into an investigation of a bond coat to provide a strong and permanent bond between glass and cement mortars. A rather complete study of proper mortar mixes for glass block construction is under way.

Considerable attention has been devoted to the design of the blocks, with respect to glass thickness and distribution, and as this work progresses it will be possible ultimately to indicate with assurance just what the proper glass block should be to give satisfactory service under all conditions.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, G. W. Morey.
Vice-Chairman, U. E. Bowes.
Secretary, Louis Navias.

Respectfully submitted on behalf of the committee,

G. W. MOREY,
Chairman.

LOUIS NAVIAS,
Secretary.

REPORT OF COMMITTEE C-15
ON
MANUFACTURED MASONRY UNITS

Since the organization of Committee C-15 on Manufactured Masonry Units by the merging of Committees C-3 on Brick and C-10 on Hollow Masonry Building Units, the committee has held three meetings, one on June 30, 1937, in New York City during the annual meeting of the Society, one on November 17, 1937, in Washington, D. C., and one on March 17, 1938, in Pittsburgh, Pa. The committee, with advice from the officers of the Society, has defined its field of activities. They include the preparation of specifications, methods of testing and definitions relating to units of inorganic substances intended for use in the construction of masonry, except those under the jurisdiction of Committees C-8 on Refractories, C-11 on Gypsum, C-14 on Glass and Glass Products, and C-18 on Natural Building Stones and Slate.

Subsequent to the 1937 annual meeting, Committee C-15 presented to the Society on August 26, 1937, through Committee E-10 on Standards, revisions of the Tentative Specifications for Paving Brick (C 7 – 37 T) and for Glazed Building Units (C 126 – 36 T). These recommendations were accepted[1] and the revised specifications appear in the 1937 *Proceedings*.[2]

Recommendations Affecting Standards:

As a result of its activitues during the year, the committee is submitting four new tentative standards, a revision of a tentative standard, tentative revisions of two standards, and is requesting the withdrawal of two standards. The standards to which these recommendations pertain are listed in Table I. This table shows the results of the letter ballot vote of the committee, which consists of 55 members.

Clay Building Brick:

During the past four years, Subcommittee II on Clay Building Brick (J. W. McBurney, chairman) has actively sponsored research on the weathering properties of brick. Members of the committee have recognized that the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30) are incomplete because they do not include requirements pertaining to the resistance of brick to the agents of weathering. Following intensive studies of simple methods for predicting the resistance of clay brick to frost action by means of properties which can be determined easily and quickly, the committee prepared the present Tentative Specifications C 62 – 37 T. The data which serve as a basis for this tentative standard are summarized or referred to in the annual reports of Committee C-3 on Brick for the years 1935 and 1936.[3] Committee C-15 is now recommending the withdrawal of Standard Specifications C 62 – 30.[1] Specifications C 62 – 37 T will remain as tentative for the present as the committee desires to continue its studies of the applicability of the specifications to bricks of certain districts.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee C-15 reported the following results of the letter ballot vote of a total of 49 ballots returned from a committee membership of 53: C 7 – 37 T, affirmative 41, negative 1, ballots marked "not voting" 7; C 126 – 36 T, affirmative 40, negative 0, ballots marked "not voting" 9.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 740, 736 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 499, 495.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 243 (1935); Vol. 36, Part I, p. 260 (1936).

Concrete Units:

During the year Subcommittee III on Concrete Units (W. G. Kaiser, Chairman) prepared new Tentative Specifications for Concrete Masonry Units for Use in Construction of Catch Basins and Manholes, which are recommended for publication as tentative, as appended hereto.[2] Heretofore, the only nationally recognized specifications for these products have been those of the American Concrete Institute, which organization is now looking to the A.S.T.M. for specification of this type. The proposed specifications are similar to the A.C.I. specifications, the only major revision being an increase in the requirements for minimum compressive strength.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Specifications for Concrete Masonry Units for Use in Construction of Catch Basins and Manholes	36	3	7
Specifications for Sand-Lime Building Brick (C 73 – 38 T)	38	1	7
Specifications for Structural Clay Load-Bearing Wall Tile (C 34 – 38 T)	38	2	9
Methods of Sampling and Testing Concrete Masonry Units	43	1	9
II. REVISION OF TENTATIVE STANDARD			
Specifications for Paving Brick (C 7 – 37 T)	42	0	7
Specifications and Methods of Test for Concrete Units for Non-Load-Bearing Masonry (C 129 – 37 T)	38	0	11
III. TENTATIVE REVISIONS OF STANDARDS			
Specifications for Structural Clay Non-Load-Bearing Tile (C 56 – 36)	39	0	10
Specifications for Structural Clay Floor Tile (C 57 – 36)	38	0	11
IV. WITHDRAWAL OF STANDARDS			
Specifications for Sand-Lime Building Brick (C 73 – 37)	37	2	7
Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30)	45	0	4

In view of the fact that the methods of testing concrete units are the same for the various types of products covered by the new specifications and by the existing Standard Specifications and Tests for Load-Bearing Concrete Masonry Units (C 90 – 36) and the Tentative Specifications and Methods of Test for Concrete Units for Non-Load-Bearing Masonry (C 129 – 37 T), the committee is recommending the separation of the methods of sampling and testing from the specifications. The complete methods are accordingly recommended for publication as new tentative methods, entitled Tentative Methods of Sampling and Testing Concrete Masonry Units, appended hereto.[3] The new methods are to replace immediately the present methods appearing in Sections 10 to 25 of Tentative Specifications C 129, and are in effect a tentative revision of and will replace when adopted as standard next year, the methods described in Sections 10 to 25 of Standard Specifications C 90.

In addition to this change, other minor editorial improvements in arrangement and text are being made in Specifications C 129 and C 90.

Sand-Lime Brick:

As a result of investigations conducted by Subcommittee IV on Sand-Lime Brick (C. H. Carmichael, chairman) which indicated that the resistance of sand-lime brick to frost action[1] is closely related to strength when the materials and workmanship conform to the usual requirements, the committee has prepared new Tentative Specifications for Sand-Lime Building Brick, which are recommended for publication as tentative as appended hereto.[2] These specifications are to replace the present Standard Specifications for Sand-Lime Building Brick (C 73 –37)[3] which are recommended to be withdrawn.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 119.

[2] See p. 785.

[3] See p. 783.

Paving Brick:

A survey of the practices of various laboratories conducted by Subcommittee V on Paving Brick (F. H. Jackson, chairman) indicated that the practice in controlling the moisture content of bricks subjected to the rattler test was not uniform. For the purpose of defining the procedure more closely, the committee is recommending the following revision in the Tentative Specifications for Paving Brick (C 7 – 37 T):[4]

Section 24.—Change to read as follows by the addition of the italicized words:

> 24. The number of brick per test shall be ten whole bricks for all weights of brick, and the brick shall be weighed to the nearest 0.1 lb. *Brick shall be surface dry when tested.* No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

Glazed Units:

Subcommittee VII on Glazed Brick and Tile (J. R. Kauffman, chairman) has been enlarged to include representatives of the architectural terra cotta industry. It is now making plans to cooperate with Rutgers University in carrying out a survey of the properties of glazed building units. Through the courtesy of Professors George H. Brown and John R. Kauffman, the facilities of the ceramic laboratory at the University have been generously offered for conducting the laboratory tests in the survey.

Structural Clay Tile:

Discussions of the relative merits of controlling the desired qualities of structural clay tile by limitations on weight or by those on dimensions and shape factors were continued during the year by Subcommittee VIII on Structural Clay Tile (F. E. Emery, chairman). A method of specifying dimensions and shape, which has the support of a greater proportion of the members of the committee than any hitherto considered, has now been approved by the committee. Although all of the details have not been settled, the committee recommends for publication as tentative new Tentative Specifications for Structural Clay Load-Bearing Wall Tile, as appended hereto,[5] to replace when adopted the present Standard Specifications C 34 – 36, and also recommends for publication as tentative a revision of the Standard Specifications for Structural Clay Non-Load-Bearing Tile (C 56 – 36) and for Structural Clay Floor Tile (C 57 – 36), as appended hereto.[6]

Investigation on Methods of Capping Structural Clay Tile:

The investigation on methods of capping structural clay tile being carried out at Rensselaer Polytechnic Institute under the direction of Prof. T. R. Lawson is nearing completion. A report on the investigation will be forthcoming shortly.

Tests for Brick Prisms:

Under the sponsorship of the Working Committee on Tests for Brick Prisms

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[1] H. F. McMurdie, "Absorption and Strength of Commercial Sand-Lime Brick," *Rock Products*, Vol. 32, p. 67 (1929).

H. F. McMurdie, "Results of Freezing and Thawing Tests of Sand-Lime Brick," *Rock Products*, Vol. 34, p. 53 (1931).

John W. McBurney and Allan R. Eberle, "Strength, Water Absorption and Resistance to Freezing and Thawing of Sand-Lime Brick," *Journal of Research*, Nat. Bur. Standards, Vol. 20, p. 67, *Research Paper* 1065 (1938).

[2] See p. 768.

[3] 1937 Supplement to Book of A.S.T.M. Standards, p. 76.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 740 (1937); 1937 Book of A.S.T.M. Tentative Standards, p. 499.

[5] See p. 779.

[6] See pp. 1324 and 1325.

(H. C. Plummer, chairman), an investigation of the apparent strength of brick masonry prisms of various ratios of height to least width was carried out at Columbia University under the direction of Prof. W. J. Krefeld. A paper by Mr. Krefeld describing the investigation, entitled "Effect of Shape of Specimen on the Apparent Compressive Strength of Brick Masonry," appears as an Appendix to this report.

Freezing-and-Thawing Tests for Masonry Units:

The results of an investigation of the effect of differences in the technique of making laboratory freezing-and-thawing tests on the disintegration of clay building brick are described in a paper by J. W. McBurney entitled "The Freezing-and-Thawing Test for Building Brick"[1] being presented at this annual meeting of the Society.

Modular Sizes for Masonry Units:

The Working Committee on Modular Sizes for Masonry Units (Frederick Heath, Jr., chairman) is undertaking the preparation of a list of sizes of building units which conform to a single module. The purpose of the present activity is to develop a list of sizes which will make possible the assembly of the various structural members of a building without extensive cutting and waste. If this can be done it is proposed that the list of sizes will be published for information to obtain the reaction of producers and consumers of building materials.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 54 members; 49 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

D. E. PARSONS,
Chairman.

J. W. WHITTEMORE,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 470 (1938).

APPENDIX

EFFECT OF SHAPE OF SPECIMEN ON THE APPARENT COMPRESSIVE STRENGTH OF BRICK MASONRY

By W. J. Krefeld[1]

In view of the variables entering into the properties of brick masonry, it is understandable that specimens in the form of piers, wall sections, or wallettes have been employed for the determination of compressive strength or other physical properties. The shape and size of these specimens have usually been determined either by the facilities for testing available or the influence of the variable under investigation. While the many tests recorded give valuable information, it is difficult to correlate the results from different sources because of the effect of shape and size of specimen.

With the development of reinforced brick masonry, it is becoming more necessary to establish a standard form of test specimen whose recorded strength will serve as an index of the quality of masonry corresponding to the adoption of a standard cylinder specimen for concrete. Municipal building agencies have required the testing of masonry specimens cut from existing walls in order to determine its quality and compliance with code requirements. There appears to be no specification for the shape and size of such specimens, although it is clear that any effect which the type of specimen may have on the recorded strength will influence the permissible working stresses as determined by the operating code.

The purpose of this investigation was the determination of the effect of shape of specimen on the recorded compressive strength of brick masonry. The specimens were limited to two sections with varying heights, composed of one lot of brick and one mortar mix. The program was intended to serve as a guide for further study in which specimens of other sections and materials might be employed. This investigation was conducted by the Department of Civil Engineering Research Laboratories of Columbia University in cooperation with Committee C-15 on Manufactured Masonry Units.

MATERIAL AND SPECIMENS

The brick used in the construction of all specimens were from one lot of soft mud, sand struck clay brick uniformly fired in a tunnel kiln, manufactured at New Britain, Conn. The physical properties of these bricks as determined in accordance with standard procedure,[2] are shown in Table I.

The "ratio of absorption" shown represents the weight of water absorbed after immersing one face of the dry brick in water to a depth of $\frac{1}{8}$ in. for the time specified. This absorption is expressed in terms of grams per 30 sq. in. of surface immersed.[3]

The mortar used for all specimens was a mixture of 0.85 portland cement: 0.15 lime putty: 3 sand by volume, representing a 1:3 mix with 15 per cent replacement of cement by lime putty. The corresponding mix by weight for the materials used is 1 portland cement: 0.152 lime putty: 3. 6 sand. The putty was prepared with measured quantities of pulverized quicklime and water in batches sufficient for the progress

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[1] Associate Professor of Civil Engineering, and Director of Engineering Materials Research Laboratories, Columbia University, New York City.

[2] Standard Methods of Testing Brick (Modulus of Rupture, Compressive Strength, Absorption) (C 67 – 37), 1937 Supplement to Book of A.S.T.M. Standards, p. 78.

[3] According to procedure of National Bureau of Standards.

TABLE I.—PHYSICAL PROPERTIES OF CLAY BRICK.

	Compressive Strength, lb. per sq. in.	Modulus of Rupture, lb. per sq. in.	Absorption, per cent		Ratio of Absorption, $\frac{C}{B}$	Rate of Absorption, g. per 30 sq. in.	
			24 hr. Cold	5 hr. Boiling		1 min.	3 min.
Maximum	7600	1545	19.7	22.7	0.893	57.0	93.8
Minimum	3520	311	9.8	13.4	0.731	17.5	28.9
Average	5124	689	16.1	19.1	0.84	39.7	67.1

TABLE II.—COMPRESSION TESTS ON BRICK MASONRY WITH VARIABLE HEIGHT-THICKNESS RATIO.

Specimen	Section, in.	Height, in.	Ratio, Height to Thickness, $\frac{h}{t}$	Compressive Strength, lb. per sq. in.		Modulus of Elasticity, lb. per sq. in.	Mortar Strength, lb. per sq. in.[a]	
				First Crack	Maximum Load		Cured Wet	Cured Dry
No. 20A	8.02 by 16.60	8.67	1.08	2180	3400	....	2856	1523
No. 20B	7.98 by 16.50	8.95	1.12	2750	3270	....	2856	1523
No. 20C	7.90 by 16.30	8.55	1.08	2880	3602	....	2856	1523
Average		8.72	1.09	2603	3424		2856	1523
No. 1	7.95 by 16.50	14.18	1.78	1680	2230	....	2741	1968
No. 10	7.88 by 16.40	14.15	1.79	1685	2380	....	3188	1536
No. 20	7.90 by 16.30	14.18	1.80	1905	2540	....	2856	1523
Average		14.17	1.79	1757	2383		2928	1676
No. 2	7.95 by 16.50	25.0	3.14	1145	1658	749 000	2741	1968
No. 9	7.95 by 16.35	25.3	3.18	1085	1868	823 000	3188	1536
No. 19	7.90 by 16.45	25.55	3.23	1620	2135	941 000	2639	1762
No. 27	7.95 by 16.50	25.3	3.18	1372	2039	850 000	2678	1492
Average		25.29	3.18	1305	1925	840 800	2811	1689
No. 3	7.95 by 16.50	49.75	6.26	955	1272	833 000	2684	1328
No. 12	8.00 by 16.40	50.0	6.25	1220	1506	893 000	2178	1532
No. 18	8.00 by 16.50	50.10	6.26	1280	1470	785 000	2437	1730
No. 26	7.95 by 16.50	50.25	6.32	1395	1822	924 000	3214	1834
Average		50.02	6.27	1212	1518	858 800	2628	1606
No. 4	7.95 by 16.44	97.3	12.23	1330	1400	800 000	2844	1690
No. 11	8.00 by 16.40	97.0	12.12	1128	1440	885 000	2606	1384
No. 17	8.02 by 16.55	97.7	12.15	1035	1366	923 000	3154	1815
Average		97.3	12.17	1164	1402	869 300	2868	1630
No. 5	12.0 by 16.40	14.15	1.18	1985	2960	....	3456	1819
No. 13	12.05 by 16.50	14.40	1.20	2065	2862	....	2520	1502
No. 22	11.95 by 16.30	14.22	1.19	2270	2975	....	3126	1678
Average		14.26	1.19	2107	2932		3034	1667
No. 6	11.95 by 16.55	25.20	2.11	1138	2130	952 000	3456	1819
No. 14	11.95 by 16.30	25.32	2.12	1160	2233	1 117 000	2520	1502
No. 21	11.95 by 16.50	25.25	2.12	1420	2275	992 000	2547	1462
Average		25.26	2.12	1239	2213	1 020 300	2841	1594
No. 7	12.0 by 16.35	50.40	4.20	1375	1775	952 000	3144	1895
No. 16	12.0 by 16.45	49.83	4.15	1268	1570	1 058 000	2588	2305
No. 23	11.90 by 16.25	50.20	4.22	1340	1730	1 033 000	3079	1552
No. 25	12.05 by 16.48	50.70	4.21	1135	1687	1 161 000	3378	1351
Average		50.28	4.20	1280	1691	1 051 000	3047	1776
No. 8	11.95 by 16.37	97.0	8.11	1073	1345	778 000	2925	2188
No. 15	12.02 by 16.40	97.1	8.08	1430	1630	962 000	2621	1519
No. 24	12.0 by 16.32	97.0	8.08	1230	1488	905 000	2543	1833
Average		97.0	8.09	1244	1488	881 700	2696	1847

[a] Values indicate average of 4 cubes for each condition. The heights shown correspond to 3, 5, 9, 18, and 35 courses.

of the masonry construction without appreciable loss in moisture content. This putty contained 57.5 per cent moisture when used. The quantities of materials including water entering into the mortar mix were controlled by weight. The consistency of all batches was quite uniform and corresponded to a flow of 165. Specimens in the form of 2 by 2-in. cubes were molded from batches used in the construction of each pier. Half of the specimens thus sampled were cured in water while the remainder were stored with the masonry under room temperature conditions and tested air dry.

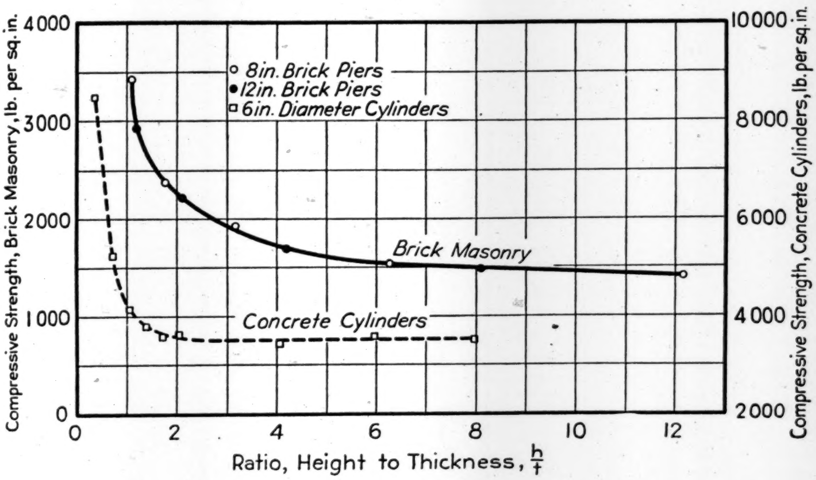

FIG. 1.—Variation of Compressive Strength of Concrete Cylinders and Brick Masonry with Shape of Specimen.

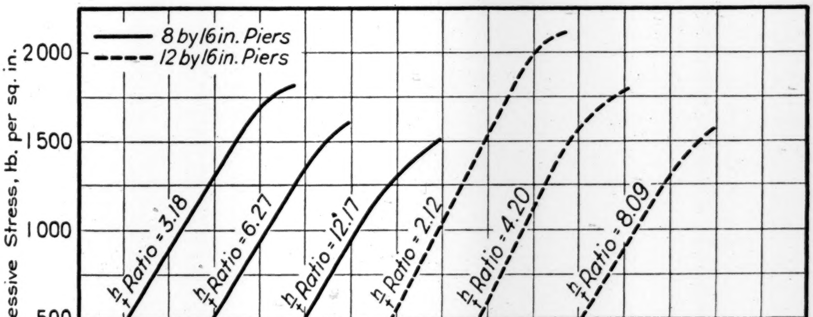

FIG. 2.—Average Stress-Strain Relations for Brick Masonry.

Two series of masonry piers were constructed with 8 by 16 in. and 12 by 16 in. cross-sections, respectively. A total of 30 piers included specimens with heights ranging from 8.5 to 97 in. (3 to 35 courses).

Three (or four) piers of each section and height were constructed as shown in Table II. The variable dimensions provided specimens with $\frac{h}{t}$ ratios ranging from 1 to 12 approximately. All piers were laid with common bond including headers at every sixth course (Fig. 3). The brick were laid dry with $\frac{3}{8}$-in. joints finished with a round jointer. The piers were constructed on 14 by 18 by $\frac{1}{2}$ in. flat steel plates and were capped with similar plates. These plates provided plane end bearing surfaces and also facilitated the handling. The specimens were stored at an average temperature of 70 F. and were tested air dry at 28 days.

A supplementary series of tests on concrete cylinders included specimens with 6-in. diameters and heights ranging from 2 to 48 in. The concrete mix was 1:2.5:4 by volume with 7.0 gal. of water per sack (neglecting absorption) producing a consistency corresponding to a 3.5-in. slump. The concrete was machine-mixed and each set of specimens was molded from a single batch. The ends of these cylinders were finished on a rubbing bed to ensure plane surfaces. All specimens were moist-room cured and tested at 28 days.

TEST PROCEDURE

The masonry piers were subjected to compression test in a 600,000-lb. Southwark-Emery testing machine operated so as to apply load at the rate of 15,000 lb. per min. Compressive strains were measured on the opposite faces of the 2, 4 and 8 ft. piers from which the modulus of elasticity was determined. A gage length of 20 in. was used for the 2-ft. piers and 36 in. for the others. These strains were measured by means of recording dials and a weighted steel wire attached to steel pins bedded in the mortar joints.

The concrete cylinders were tested for compressive strength in accordance with standard procedure.

TEST DATA

The results of tests made on the masonry piers and concrete cylinders are shown in Tables II and III. These data are shown graphically in Fig. 1.

The variation of compressive strength of brick masonry with $\frac{h}{t}$ ratio for both the 8 by 16 in. and 12 by 16 in. sections is represented by a single curve. These data indicate that for the sections tested, the "normal" compressive strength is obtained from specimens having an $\frac{h}{t}$ ratio of 6 or greater, when for all practical purposes the strength approaches a constant value. For an $\frac{h}{t}$ ratio less than 6, the apparent strength is influenced by a form factor. In the case of concrete cylinders, it is of interest to note that the strength is practically constant for $\frac{h}{t}$ ratios greater than 2, the usual 6 by 12 in. standard specimen. The test data agree

TABLE III.—COMPRESSIVE STRENGTH OF CONCRETE CYLINDERS 6 IN. IN DIAMETER, VARIABLE HEIGHT.

Nominal Height of Cylinder, in.	Compressive Strength, lb. per sq. in.						Average Ratio, Height to Thickness, $\frac{h}{}$
	Series 1	Series 2	Series 3	Series 4[a]	Series 5[a]	Average	
2	8100	8150	8033	8868	9185	8467	0.36
4	4970	5050	5030	5593	5461	5221	0.71
6	3920	3695	4290	4353	4639	4179	1.03
8	3550	3400	4163	3773	4174	3812	1.37
10	3270	3275	3538	3818	4098	3600	1.70
12	3525	3310	3673	3976	3890	3675	2.02
24	3325	3460	3295	3452	3778	3462	4.04
36	3345	3485	3500	3820	3865	3603	5.95
48	3390	3485	3344	3567	3813	3520	7.96

[a] Series 4 and 5, same mix but different cement and sand.

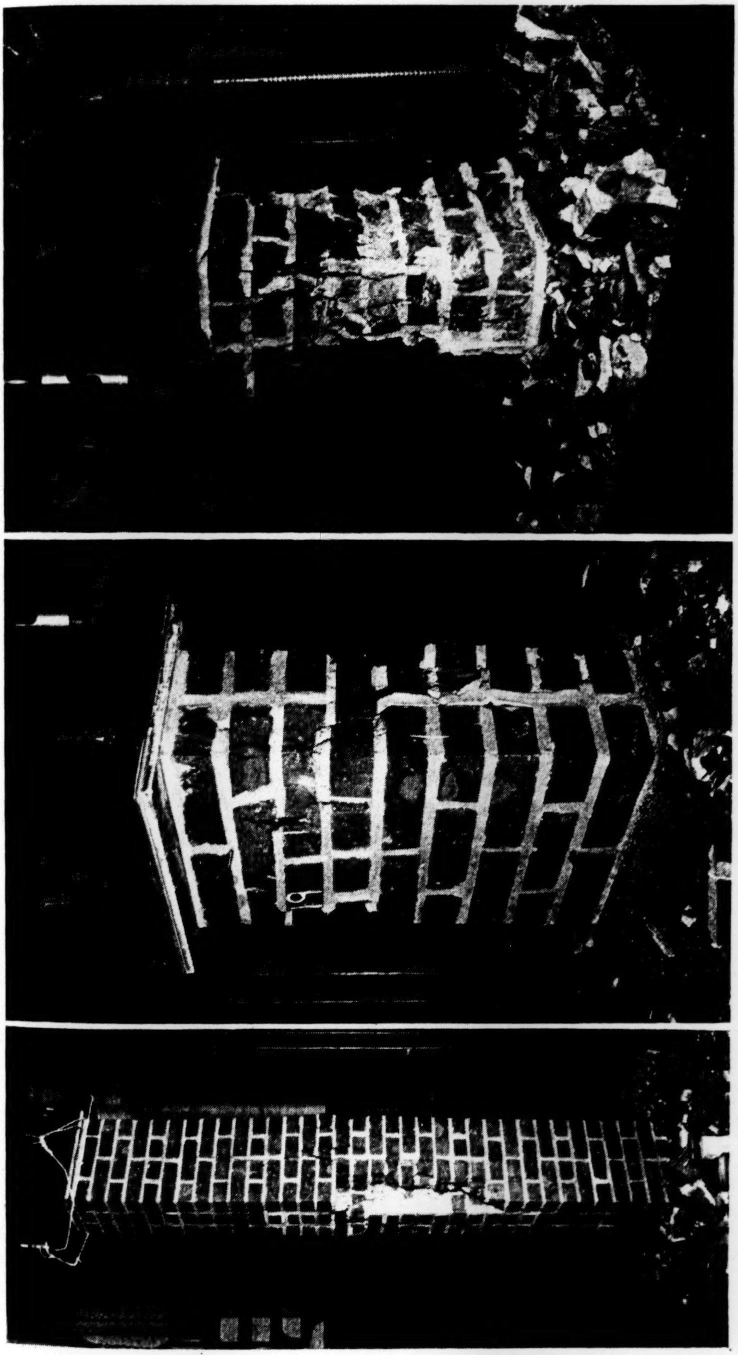

FIG. 3.—Typical Fractures of 8 and 12-in. Masonry Piers Showing Diagonal Fracture of Shorter Specimens and Tendency to Split in Specimens with Large $\frac{h}{t}$ Ratio.

very closely with the recommended correction factors included in A.S.T.M. Methods C 42 - 31.[1] It would be expected that the strengths of both materials would decrease at some $\frac{h}{t}$ ratio larger than that investigated, when column action becomes effective.

A possible explanation of the variation of strength of the masonry piers is furnished by the character of failure. It was noted that in the piers of both sections with $\frac{h}{t}$ ratios of 4 or less the fractures were by diagonal shear similar to that of a monolithic specimen. The specimens with greater $\frac{h}{t}$ ratios failed by splitting down the vertical joints of the narrower face, across headers, followed by an outward bulging of the 16-in. faces and crushing of the brick. The fact that these outer 4-in. sections finally crushed at different elevations on opposite sides indicates that the failure was in "detail," each remaining section acting as an independent column. Figure 3 includes typical views of these fractures.

It should be noted that these masonry specimens were all of the same materials and represent only two rectangular sections. What the relations may be for other shapes or materials cannot be concluded from these tests but it is reasonable to assume that similar "form" factors will apply and perhaps a series of approximately parallel curves would result from variations in brick and mortar strength, bonding and sectional dimensions. An extension of this investigation to include these variables would be desirable.

Correction factors applicable to the test data here presented are shown in Table IV. These are presented as a guide pending further information showing the effect of other variables. The application of such correction factors would permit specimens of economical dimensions to be used for determination of compressive strength of brick masonry and reduction of results obtained from dissimilar specimens to a common basis of comparison.

In regard to the mortar strengths shown in Table II, it is not likely that the strength of either the wet or dry specimens is indicative of the strength of the mortar in the piers at the time of test. The observed condition of the mortar after failure of the piers showed somewhat drier material extending about $\frac{1}{4}$ in. from the face and moist mortar inside. In view of the care in proportioning the mortar and uniformity of the consistency, the variations in the wet specimens can only be explained by the difficulties of securing a representative sample from a large batch. The average strength of the mortar was 2856 lb. per sq. in., water cured; 1667 lb. per sq. in., air cured.

TABLE IV.—STRENGTH CORRECTION FACTORS FOR BRICK MASONRY PRISMS.

Ratio, Height to Thickness, $\frac{h}{t}$	Strength Correction Factor
1.1	0.45
1.5	0.59
2.0	0.67
2.5	0.75
3.0	0.80
3.5	0.85
4.0	0.89
4.5	0.93
5.0	0.96
5.5	0.98
6.0	1.00
8.0	1.03
10.0	1.06
12.0	1.09

The modulus of elasticity (Table II) shows no decided influence of height of pier (or gage length) in one series, but there appears to be a somewhat higher modulus for the 12-in. sections. Figure 2 represents the average stress-strain relation for each section tested.

SUMMARY

These data indicate that:

1. The compressive strength of brick masonry is influenced by the $\frac{h}{t}$ ratio of the test specimen.

2. The variation of strength of 8 by 16 in. and 12 by 16 in. piers with $\frac{h}{t}$ ratio follows a common relationship.

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[1] Standard Methods of Securing Specimens of Hardened Concrete from the Structure (C 42 - 31), 1936 Book of A.S.T.M. Standards, Part II, p. 351.

3. The "normal" strength of masonry having these sections is recorded for an $\frac{h}{t}$ ratio of 6 or greater, and for smaller ratios the apparent strength is increasingly greater.

4. Suitable correction factors would permit the use of relatively short piers to be used for determination of the quality of the masonry. Although greater economy will result from the use of the smaller specimens, it is not advisable to adopt a specimen with $\frac{h}{t}$ ratio less than 3 or 4 due to the more pronounced influence of shape.

These conclusions are limited to the specimens tested. The influence of other factors such as brick and mortar, strength, bonding, and other sectional dimensions, might well be included in a more extended program.

Acknowledgment:

The author wishes to acknowledge the cooperation of D. E. Parsons, chairman of Committee C-15, H. C. Plummer, chairman of the Working Committee on Tests for Brick Prisms, F. Heath of Colonial Clays, Inc.; and J. H. Hansen of the Brick Manufacturers Association of New York for his interest. The assistance of the Donnelly Brick Co. in furnishing the necessary brick is appreciated. Particular acknowledgment is made of the services rendered by P. H. Ripley, Assistant Engineer of the Laboratory staff, who constructed all of the test specimens and summarized the test data.

REPORT OF COMMITTEE C-18

ON

NATURAL BUILDING STONES AND SLATE

Committee C-18 on Natural Building Stones and Slate held one meeting during the year in connection with the annual meeting of the Society. Along with this meeting, informal meetings of several of its subcommittees were also held.

The contemplated action on modification of the existing Tentative Method of Compression Testing of Natural Building Stone (C 98 – 30 T) that would put this method in final form for adoption as standard could not be taken in view of the wide difference of opinion with respect to the size and form of test specimens which was found, by a canvass of testing laboratories, to exist among the laboratory authorities consulted. This requires further study and the proposal has therefore been returned to Subcommittee III on Testing Procedure with instructions that suitable arrangements be made to have the necessary series of tests conducted as soon as possible in order to develop the information required on certain important factors upon which definite information is not available at the present time.

The recommendation of Subcommittee III that the Tentative Method of Tension Testing of Natural Building Stone (C 103 – 32 T) be discontinued was approved subject to a letter ballot vote of the committee membership.

A form of abrasion test procedure for determining the wear resistance of natural stone and slate used for walkway surfaces under foot traffic, which was proposed at a former meeting, has now been developed in preliminary form, based upon the investigations of several authorities who have previously reported upon their investigations and findings in connection with this form of test. This procedure, subject to editing and coordination with previous work will shortly be sent out to the membership of Committee C-18 for letter ballot vote on the recommendation that it be presented to the Society for publication as tentative.

Proposed modifications of the existing definitions of certain of the terms applying to the work of this committee were discussed at some length at the June meeting, along with the proposal that certain other terms applying to natural stone be similarly defined, but action was withheld until after the meeting of Subcommittee VI on Terms and Definitions to be held subsequent to the annual meeting.

A report from Subcommittee IV on Uniform Cubing of Stone was received and discussed and after further editing its proposal was ordered sent out to the committee membership for renewed consideration, pending the call for a letter ballot vote on submitting it to the Society for publication as tentative.

Progress on the projects for standardization of commercial samples and upon the uniform names and descriptions of surface finishes for stone was reported by the two subcommittees having these assignments.

Regulations proposed to govern the work of this committee to supplement the Society Regulations Governing Standing Committees, conforming in all major provisions to those now in use by a number of other committees, were presented and with minor changes were approved for transmission to the committee membership for action by letter ballot.

Work for the ensuing year will consist mainly of completing the projects now under way, with the possible appointment of one or two new subcommittees to develop specifications for certain types of stone embraced within the scope of the committee's program, also the conduct of certain similar activities on behalf of the Slate Division of the committee in response to a stated need for that and an appropriate participation on the part of the industries interested therein.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, Theodore I. Coe.
Vice-Chairman, W. C. Clark.
Secretary, H. S. Brightly.

This report has been submitted to letter ballot of the committee, which consists of 15 members; 12 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

THEODORE I. COE,
Chairman.

H. S. BRIGHTLY,
Secretary.

REPORT OF SECTIONAL COMMITTEE

ON

SPECIFICATIONS FOR PLASTERING

A.S.A PROJECT: A42

Sectional Committee A42 on Specifications for Plastering has held one meeting during the past year, in Washington, D. C., on May 25, 1938. Most of the activities of the committee have been conducted by correspondence. The work of Committee A42 has included:

1. The preparation, circulation, amending, and balloting upon drafts of Proposed American Standard Specifications for Gypsum Plastering, Including Requirements for Lathing. Three drafts of this document have been circulated; two ballots were taken upon the standard as a whole. The final ballot, as of February 17, 1938, resulted in a vote of 27 affirmative and 2 negative out of a voting membership of 30. This proposed standard has, therefore, been transmitted to the sponsors (American Society for Testing Materials and American Institute of Architects) with the request that they submit it to the American Standards Association for approval as an American standard.[1]

2. A draft of a Proposed Standard for Portland-Cement Stucco and Portland-Cement Plaster has been prepared and distributed to the committee. This draft was considered at the meeting held on May 25 and a new draft is in course of preparation.

The changes in the personnel of Committee A42 are as follows:

S. Walter Stauffer replaced Lee S. Trainor as the representative of the National Lime Association.

F. E. Pearson replaced F. J. Duffy as the representative of the Building Trades Employers' Association of the City of New York.

F. C. Welch replaced J. A. Murray as one of the five representatives of the American Society for Testing Materials.

The personnel of Sectional Committee A42 was approved by the Standards Council of the American Standards Association on April 14, 1938.

At the meeting in Washington, May 25, officers were elected as follows:

Chairman, Walter R. McCornack
Vice-Chairman, Theodore Irving Coe
Secretary, J. W. McBurney

F. R. Wragg was reappointed Drafting Secretary.

Respectfully submitted on behalf of the committee,

WALTER R. MCCORNACK,
Chairman.

J. W. MCBURNEY,
Secretary.

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[1] The specifications were approved as American standard on September 29, 1938, and assigned the A.S.A. designation A42.1-1938.

REPORT OF COMMITTEE D-1

ON

PAINT, VARNISH, LACQUER, AND RELATED PRODUCTS

Committee D-1 on Paint, Varnish, Lacquer, and Related Products held a meeting on March 8, 1938, at the Seneca Hotel, Rochester, N. Y., during the group meetings of A.S.T.M. committees.

During the year, upon the recommendation of Committee D-1, the following A.S.T.M. standards were submitted by the Society to the American Standards Association and approved as American standards:

Standard Specifications for:

Raw Linseed Oil (D 234 – 28) (A.S.A. No. K34–1937),
Boiled Linseed Oil (D 260 – 33) (A.S.A. No. K35–1937),
Bone Black (D 210 – 30) (A.S.A. No. K36–1937),
Chrome Oxide Green (D 263 – 28) (A.S.A. No. K37–1937),
Titanium Barium Pigment (D 382 – 35) (A.S.A. No. K38–1937),
Titanium Calcium Pigment (D 383 – 35) (A.S.A. No. K39–1937),
Titanium Dioxide (D 384 – 36) (A.S.A. No. K40–1937),

Standard Methods of:

Test for Specific Gravity of Pigments (D 153 – 27) (A.S.A. No. K41–1937),
Test for Coarse Particles in Dry Pigments and Coarse Particles and Skins in Mixtures of Pigments and Vehicles (D 185 – 37) (A.S.A. No. K42–1937),
Routine Analysis of Titanium Pigments (D 186 – 37) (A.S.A. No. K43–1937), and
Routine Analysis of Yellow, Orange, Red and Brown Pigments Containing Iron and Manganese (D 50 – 36) (A.S.A. No. K44–1937).

The committee recommends that the Society continue as a member-body in the Inter-Society Color Council for another year, and that participation by Committee D-1 in the activities of the Council be conducted through M. Rea Paul who is one of the official delegates from the Society.

Consideration is being given by the committee to the development of a research project that would cover the problems of adhesion and adhesion testing. It is hoped that this project when developed will be of a character that will hold sufficient interest for the paint, varnish, and lacquer industry to have the necessary research work financed by that group.

Committee D-1 has, during the past year, encouraged the presentation of brief papers at its meetings. These papers were as follows:

"Development of Hiding Power Test Methods," by D. L. Gamble,
"A Proposed Test for Determining the Reactivity of Varnishes and Paint Liquids,"[1] by Sidney Werthan,
"Determining the Depth of Color in Varnishes,"[1] by G. G. Sward,
"Accelerated Testing of House Paints," by C. H. Rose,
"Accelerated Testing of Paints for Iron and Steel,"[2] by J. C. Moore,
"Some Requirements for Cold Water Paste Paints," by A. J. Eickhoff, and
"Present Status of Accelerated Testing and Plans for Its Further Development," by H. A. Nelson.

One new subcommittee and one special committee have been organized during the past year, as follows: Subcommittee XXIX on Painting of Structural Iron and Steel, under the chairmanship of A. J. Eickhoff, and a Papers Committee, under the chairmanship of M. Rea Paul.

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[1] Published in ASTM Bulletin, No. 88, October, 1937, p. 16.

[2] Published in ASTM Bulletin, No. 89, December, 1937, p. 25.

Since the last annual meeting, 15 new members have been elected, 13 resignations have been accepted and 1 death reported, leaving a total membership of 215.

Of the three advisers and thirteen D-1 subcommittees, four furnished reports of progress and six submitted detailed reports affecting standards that have resulted in the committee making the recommendations given below to be acted upon at the annual meeting.

RECOMMENDATIONS AFFECTING STANDARDS

In this report, recommendations affecting standards and tentative standards are noted in brief form below, together with the results of the letter ballot. These recommendations are explained in the reports of the subcommittees directly responsible for them.

New Tentative Standards:

The committee submits for publication as tentative the following five new specifications and two methods of test, as appended hereto:[1]

Tentative Specifications for:

- Aluminum Pigment Paste for Paint, proposed by Subcommittee XV,
- C. P. Para Red Toner, proposed by Subcommittee XV,
- C. P. Zinc Yellow (Zinc Chromate), proposed by Subcommittee XV,
- Titanium Dioxide Pigments, representing a revision of Standard Specifications D 382, D 383, D 384, and Tentative Specifications D 442 – 37 T, as proposed by Subcommittee XV, and
- Zinc Sulfide Pigments, representing revision of Standard Specifications D 208, D 385, D 386, and Tentative Specifications D 443 – 37 T, as proposed by Subcommittee XV.

Tentative Methods of:

- Sampling and Testing Aluminum Powder and Aluminum Paste, proposed by Subcommittee VIII, and
- Test for Reactivity of Paint Liquids, proposed by Subcommittee IX.

Revisions of Tentative Standards:

The committee recommends that the following tentative methods of analysis be revised, as referred to in the report of the subcommittee, and continued as tentative:

- Tentative Method of Routine Analysis of Dry Cuprous Oxide (D 283 – 37 T), proposed by Subcommittee VIII, and
- Tentative Methods of Routine Analysis of Zinc Yellow Pigment (Zinc Chromate Yellow) (D 444 – 37 T), proposed by Subcommittee VIII.

Revisions of Standards:

The committee recommends for immediate adoption, a revision in the Standard Specifications for Basic Carbonate White Lead (D 81 – 34), as proposed by Subcommittee XV, and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that these modifications may be referred to letter ballot of the Society.

The committee further recommends that the revisions proposed in the following standard specifications be accepted for publication as tentative:

Standard Specifications for:

- Red Lead (D 83 – 31), proposed by Subcommittee XV,
- Commercial Para Red (D 264 – 28), proposed by Subcommittee XV,
- Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 – 31), proposed by Subcommittee XV,
- Normal Butyl Acetate (88 to 92 per cent Grade) (D 303 – 33), proposed by Subcommittee XXV,
- Butyl Propionate (90 to 93 per cent Grade) (D 320 – 33), proposed by Subcommittee XXV, and
- Ethyl Lactate (Synthetic) (D 321 – 33), proposed by Subcommittee XXV.

Adoption of Tentative Standards as Standard:

The committee recommends that the following tentative specifications be revised as referred to in the report of the subcommittee, and approved for reference to letter ballot of the Society for adoption as standard:

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[1] See pp. 822, 826, 831, 829, 833, 835, 850.

Tentative Specifications for Basic Sulfate White Lead (D 82 – 37 T), to replace the present Standard Specifications D 82, as proposed by Subcommittee XV, and

Tentative Specifications for Blue Lead; Basic Sulfate (D 405 – 35 T), proposed by Subcommittee XV.

The committee further recommends that the following tentative specification and method be approved, without change, for reference to letter ballot of the Society for adoption as standard:

Tentative Specifications for Wood to be used as Panels in Weather Tests of Paints and Varnishes (D 358 – 35 T), proposed by Subcommittee VII, and

Tentative Methods of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number) (D 154 – 35 T), to be added to the present Standard Methods of Testing Oleo-Resinous Varnishes (D 154 – 28), as proposed by Subcommittee IX.

Withdrawal of Standard:

The committee recommends the withdrawal of the Standard Method of Test for Determination of Polishing Lubricant in Aluminum Powder for Paints (Aluminum Bronze Powder) (D 306 – 31), proposed by Subcommittee VIII, since the method of test in question is covered by a new tentative method of sampling and testing now being proposed for publication as tentative.

The above recommendations have been submitted to letter ballot of the committee, which consists of 215 members; 113 members have returned their ballots. The analysis of the vote of the committee is given in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Specifications for Aluminum Pigment Paste for Paint	71	0	42
Specifications for C. P. Para Red Toner	70	0	43
Specifications for C. P. Zinc Yellow (Zinc Chromate)	71	0	42
Specifications for Titanium Dioxide Pigments[a, b]	67	17	29
Specifications for Zinc Sulfide Pigments[b]	77	1	35
Methods of Sampling and Testing Aluminum Powder and Aluminum Paste[b]	72	1	40
Method of Test for Reactivity of Paint Liquids	70	1	42
II. REVISIONS OF TENTATIVE STANDARDS			
Method of Routine Analysis of Dry Cuprous Oxide (D 283 – 37 T)	56	0	57
Methods of Routine Analysis of Zinc Yellow Pigment (Zinc Chromate Yellow) (D 444 – 37 T)	69	0	44
III. REVISIONS OF STANDARDS			
Specifications for Basic Carbonate White Lead (D 81 – 34), immediate adoption	73	0	40
Specifications for Red Lead (D 83 – 31)	76	0	37
Specifications for Commercial Para Red (D 264 – 28)	68	0	45
Specifications for Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 – 31)	66	0	47
Specifications for Normal Butyl Acetate (88 to 92 per cent Grade) (D 303 – 33)	44	0	69
Specifications for Butyl Propionate (90 to 93 per cent Grade) (D 320 – 33)	40	0	73
Specifications for Ethyl Lactate (Synthetic) (D 321 – 33)	40	0	73
IV. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Basic Sulfate White Lead (D 82 – 37 T), as revised	65	0	48
Specifications for Blue Lead; Basic Sulfate (D 405 – 35 T), as revised	65	0	48
Specifications for Wood to be Used as Panels in Weather Tests of Paints and Varnishes (D 358 – 35 T)[c]	69	9	35
Methods of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number) (D 154 – 35 T)	69	0	44
V. WITHDRAWAL OF STANDARD			
Method of Test for Determination of Polishing Lubricant in Aluminum Powder for Paints (Aluminum Bronze Powder) (D 306 – 31)	59	0	54

[a] The classified vote on the proposed Tentative Specifications for Titanium Dioxide Pigments was as follows: Affirmative: 16 producers, 35 consumers, 16 general interests; negative: 15 producers, 1 consumer, 1 general interest.

[b] Additional revisions in these specifications and methods presented at the annual meeting are recorded in the Summary of Proceedings, p. 31, together with the confirming letter ballot in the committee.

[c] The classified vote on the adoption as standard of the Tentative Specifications for Wood to be Used as Panels in Weather Tests of Paints and Varnishes (D 358 – 35 T) was as follows: Affirmative: 3 producers, 38 consumers, 28 general interests; negative: 0 producers, 2 consumers, 7 general interests.

ACTIVITIES OF SUBCOMMITTEES

Definitions of Terms Relating to Paint Specifications (E. F. Hickson, adviser).—It is reported that consideration is to be given the preparation of a definition for baked enamel.

Anti-Fouling Paints (U. S. Navy, Bureau of Construction and Repair, adviser).—It is reported that changes are contemplated in the Standard Specifications for the Toxic Ingredients in Anti-Fouling Paints (Dry Cuprous Oxide, Dry Mercuric Oxide) (D 277 – 31).

Subcommittee VII on Accelerated Tests for Protective Coatings (H. A. Nelson, chairman).—This subcommittee recommends the adoption as standard of the Tentative Specifications for Wood to be Used as Panels in Weather Tests of Paints and Varnishes (D 358 – 35 T).[1] The subcommittee reports progress in its plan of a new approach to the fundamental problems of accelerated testing that involves the preparation of a questionnaire for distribution to the paint, varnish, and lacquer industry. Progress is reported on the work, by the groups within this subcommittee, on accelerated laboratory tests and service tests to determine color and tint retention of house paints, and also accelerated laboratory tests and service tests on enamels and on metal protective coatings.

Subcommittee VIII on Methods of Analysis of Paint Materials (E. F. Hickson, chairman).—The report of Subcommittee VIII, appended hereto, discusses in detail the several recommendations mentioned earlier in this report.

Subcommittee IX on Varnish (W. T. Pearce, chairman).—Varnishes are often required to be neutral to zinc oxide and other pigments. It was felt that a standard method would be desirable and this subcommittee has accordingly prepared a new Tentative Method of Test for Reactivity of Paint Liquids, appended hereto,[2] which describes the test procedure and system of rating the degree of thickening of varnishes, resin solutions, or other liquids used in the manufacture of paints, enamels, and lacquers.

This subcommittee also recommends the adoption as standard of the Tentative Methods of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number) (D 154 – 35 T),[3] to be added to the present Standard Methods of Testing Oleo-Resinous Varnishes (D 154 – 28).

The subcommittee reports that a new group has been formed to study the development of a more satisfactory method for determining gas-proofness of varnishes, and that a study of methods of evaluating failure of varnishes on exposure has just been completed.

Progress is reported in connection with work on methods for determining depth of color in varnishes; the approach has been so altered as to embrace a study of methods for measuring color in the dried films. As the result of a survey conducted to determine drying characteristics of varnishes as measured by manufacturers and consumers, an effort will be made to define each type of drying, after which, methods of measurement will be investigated.

Subcommittee XIII on Shellac (W. H. Gardner, chairman).—This subcommittee intends to investigate possible standards, other than iodine solutions, for determining color of shellac and shellac varnishes, and is also considering a method for the determination of orpiment and for the inclusion of a maximum limit in existing specifications for shellac and shellac varnishes.

Subcommittee XV on Specifications for Pigments Dry and in Oil when Marketed

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 895 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 696.

[2] See p. 850.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 887 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 688.

in that Form (H. E. Smith, chairman).—In the report of Subcommittee XV, appended hereto, the several recommendations mentioned earlier in this report are discussed in detail.

Subcommittee XVIII on Physical Properties of Materials (M. Rea Paul, chairman).—This subcommittee reports progress in its work of defining and specifying gloss, which is being carried on in Group 1 under the chairmanship of D. B. Judd.

Subcommittee XXV on Cellulose Ester Coatings (R. M. Carter, chairman).—This subcommittee recommends for publication as tentative, the following revision of the Standard Specifications for Normal Butyl Acetate (88 to 92 per cent Grade) (D 303 – 33),[1] for Butyl Propionate (90 to 93 per cent Grade) (D 320 – 33),[1] and for Ethyl Lactate (Synthetic) (D 321 – 33):[1]

Section 1.—Change the requirement for water to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

Water....miscible without turbidity [in all proportions] with *19 volumes of* 60° [Baumé] *A.P.I.* gasoline at 20 C.

The following editorial change is being made in the Standard Specifications for Normal Amyl Acetate (D 318 – 36):[2]

Section 2.—Change the distillation range reading "Below 150 C." to read "Above 150 C."

Subcommittee XXV is making further editorial changes in the section on properties of each of the following lacquer solvents specifications[3] by substituting for the term "60° Baumé," the appropriate A.P.I. degrees in expressing the gravity of gasoline to be used in the test for water:

Standard Specifications for:

- Ethyl Acetate (85 to 88 per cent Grade) (D 302 – 33),
- Butanol (Normal Butyl Alcohol) (D 304 – 33),
- Normal Amyl Acetate (D 318 – 36),
- Amyl Alcohol (Synthetic) (D 319 – 33),
- Acetone (D 329 – 33),
- Ethylene Glycol Mono Butyl Ether (D 330 – 35),
- Ethylene Glycol Mono Ethyl Ether (D 331 – 35), and
- Acetate Ester of Ethylene Glycol Mono Ethyl Ether (95 to 96 per cent Grade) (D 343 – 35).

The subcommittee reports progress in the development of a dilution-ratio test method for solvents and a conical mandrel test of distensibility of applied lacquer films.

Subcommittee XXVII on Specifications for Interior Flat Paint (E. F. Hickson, chairman).—This subcommittee has in hand Specifications for Interior Flat Paint (Oil or Varnish Base), Ready-Mixed and Semipaste, Light Tints and White that are being held in abeyance pending further consideration by this committee.

The election of officers for the ensuing term of two years resulted in the selection of H. E. Smith as chairman and the re-election of the present vice-chairman and secretary.

This report has been submitted to letter ballot of the committee, which consists of 215 members; 113 members returned their ballots, of whom 91 have voted affirmatively and 2 negatively.

Respectfully submitted on behalf of the committee,

ALLEN ROGERS,
Chairman.

M. REA PAUL,
Secretary.

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[1] 1936 Book of A.S.T.M. Standards, Part II, pp. 790 to 792.

[2] *Ibid.*, p. 785.

[3] *Ibid.*, pp. 784 to 796.

REPORT OF SUBCOMMITTEE VIII ON METHODS OF ANALYSIS OF PAINT MATERIALS

Cooperative Work on Analysis of Cuprous Oxides:

At the meeting of Subcommittee VIII, held in New York City on June 28, 1937, a program was outlined for the purpose of determining how closely different analysts could check each other, using the new Tentative Method of Routine Analysis of Dry Cuprous Oxide (D 283 – 37 T)[1] and the Standard Method D 283 – 36.[2] It was agreed to carry out some cooperative analyses on several samples of cuprous oxide. Röhm and Haas Co. agreed to supply the samples for this work.[3] Three samples were obtained and labelled Nos. 1, 5, and 6. About 2 lb. of each sample was mixed for several hours in a porcelain-lined pebble mill (no pebbles). The samples were then divided into small portions and mailed to the cooperators. Cooperators from whom reports were received were as follows:

G. H. Mutersbaugh, Glidden Co.
D. P. Graham, Bureau of Construction and Repair, Navy Department.
C. Y. Hopkins, National Research Council, Canada
G. G. Sward, National Paint, Varnish and Lacquer Association
J. E. Keefauver, National Bureau of Standards
W. C. Porter, National Bureau of Standards
A. L. Fowler, National Bureau of Standards
C. B. Sentel, National Bureau of Standards
J. O. Johnstone, Metals Refining Co.
L. C. Hurd, Röhm & Haas Co.

In Table I are tabulated the results of the cooperative analyses obtained by the method of Mr. L. C. Hurd. The results of the analyses in Table I are not in the same order as the list of cooperators given in the report. Instead of merely printing the averages, all the results received are included in the table. However, in calculating average deviations from the mean, some of the results (indicated in the table) were not included.

Recommendations on Standards:

The findings of the cooperative analyses of cuprous oxides, given earlier in this report, have resulted in the committee recommending that the following revisions be made in the Tentative Method of Routine Analysis of Dry Cuprous Oxide (D 283 – 37 T)[1] and that the method be continued as tentative:

Section 2.—Add a new sentence at the end of this section to read as follows:

> Commercial copper oxides appear to segregate rather easily. Therefore, the thorough mixing of the sample to insure homogeneity is an extremely important factor in obtaining concordant results.

Section 3.—Change the last two sentences of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> When the copper is completely dissolved, wash the filter thoroughly with cold water and finally, dilute the filtrate to about 200 ml. with cold water, add 5 ml. of syrupy phosphoric acid, *then 3 drops of indicator*, and titrate the cold solution at once with 0.1 N [$KMnO_4$] $K_2Cr_2O_7$ solution *(1 ml. of 0.1 N $K_2Cr_2O_7$ is equivalent to 0.0032 g. Cu.)*. [Run a blank on the reagents used, and calculate the final corrected figure to percentage of total copper (1 ml. of 0.1 N $KMnO_4$ is equivalent to 0.0032 g. Cu).]

Section 6.—Change the last four sentences of Paragraph (*a*) to read as follows by the addition of the italicized words and figure and the omission of the figure in brackets:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 855 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 675.

[2] 1936 Book of A. S. T. M. Standards, Part II, p. 624.

[3] Acknowledgment is made to the Röhm & Haas Co., Inc., for their contribution to this work.

> Break up any lumps of oxide with a stirring rod *by gentle stirring (grinding of the sample with the stirring rod is not necessary).* Violent agitation *and swishing of the solution* should be avoided. The carbon dioxide inlet should be about 5 cm. (2 in.) above the surface of the liquid (Note 6). The time required for complete solution of all cuprous oxide varies between 1 and [5] *7* min. depending upon the amount and character of the sample under investigation.

Change the last five sentences of Paragraph (*b*) to read as follows by the addition of the italicized words:

> *It is not necessary that the final wash water remaining in the filter tube be entirely removed.* Then disconnect the filter and push the pad and contents back into the flask with a glass rod. Add 15 ml. of ferric chloride solution and warm the flask *on a hot plate to just below the boiling point of the solution* to dissolve the cupric oxide - copper residue. When all particles have disappeared, cool the solution to below 40 C. and add 10 ml. of phosphoric acid and 3 drops of indicator. Titrate (*in an atmosphere of CO_2*) the solution by running the bichromate solution into the flask. The end point is evidenced by a change from pea green to an intense purple color.

The subcommittee recommends that the Tentative Methods of Routine Analysis of Zinc Yellow Pigment (Zinc Chromate Yellow) (D 444 - 37 T)[1] be revised as follows and continued as tentative:

Section 6.—Change this section from its present form, namely, omitting the footnote reference to the method of Fox and Bowles:

> 6. Weigh 3 g. of pigment and transfer to a porcelain boat. Place the boat in a combustion tube. Connect the apparatus and heat for 4 hr. The weight increase of the absorption tube represents the "combined water," report as the percentage of combined water.

to read as follows:

> 6. *Combined Water and Moisture.*—Weigh 3 g. of the pigment and transfer to a porcelain boat. Introduce the boat with the charge into a silica combustion tube of an electrically-heated combustion furnace (of the

TABLE I.—REPORT OF COOPERATIVE WORK ON THE ANALYSIS OF CUPROUS OXIDES.

SAMPLE NO. 1

Cooperator	Total Copper, per cent	Old Cuprous Oxide, per cent	New Cuprous Oxide, per cent	Copper, per cent	Cupric Oxide, per cent	Total,[f] per cent
No. 1.........	85.2	87.1	75.3	5.3 (5.11 to 5.65)	16.4	97.0
No. 2.........	85.1	86.0	71.6	5.6[e] (3.81 to 6.99)	20.0[e]	97.2
	85.3	88.2	72.1	6.9	18.1	97.1
No. 3.........	85.2	88.2	72.0	7.0	18.0	97.0
Average....	85.3	88.2	72.1	7.0	18.1	97.1
				5.6		
				5.5		
No. 4.........	85.2	85.8	74.7	6.7		
	85.1	86.0	74.2	7.1		
	85.2	87.8	72.2	6.0	16.5	96.8
	85.1	88.0	71.6	6.2	18.3	97.2
Average....	85.2	86.9	73.2	6.2	17.4	97.0
	85.0	87.6		6.7		
No. 5.........	85.0	87.6	73.2	6.6	17.0	96.9
Average....	85.0	87.6		6.7		
				6.3		
No. 6.........			74.9	6.1	16.2	96.9
				6.3		
				5.3		
	85.2	87.3		5.5		
	85.1	87.1		5.4		
Average....	85.2	87.2		5.8		
				5.0		
				4.6	18.9[a]	97.6
No. 7.........	84.7[a]	....	72.9	5.7		
				6.1		
				6.1		
				6.4		
				6.7		
Average....	....	....	......	5.8		
	81.8		70.8	7.4	14.3[e]	92.5[e]
No. 8.........	81.8[e]	81.9[e]	71.2[e]	7.0[b]	14.7	92.9
Average....	81.8		71.0	7.2	14.5	92.7
	85.4 85.4	87.7	73.3	6.5	17.3	
No. 9.........	85.7[c] 85.3[d]	87.3	73.2	6.4	17.4	97.0
	85.5 85.3	87.7	73.2	6.6	17.2	
Average.. {	85.5 85.3 85.4	87.6	73.2	6.5	17.3	
	85.5	89.2		4.9		
No. 10........	85.6	90.7	78.3[e]	4.3	14.3[e]	97.2
Average....	85.6	90.0		4.6		
Mean........	85.2	87.6	73.3	6.1	17.3	97.1
Average Deviation from Mean.	0.2	0.7	1.2	10.8	4.0	0.15

[a] Titrated with $K_2Cr_2O_7$ in CO_2 atmosphere.
[b] Titrated with $KMnO_4$. [c] Titration. [d] Electrolytic.
[e] Not used in any calculation of averages or deviations.
[f] Values in this column are the totals of the values under the columns for new cupric oxide, copper, and cuprous oxide.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 849 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 669.

TABLE I.—*Continued.*

SAMPLE No. 5

Cooperator	Total Copper, per cent	Old Cuprous Oxide, per cent	New Cuprous Oxide, per cent	Copper, per cent	Cupric Oxide, per cent	Total,[f] per cent
No. 1	84.6	81.8	79.0	1.3 (1.17 to 1.36)	16.4	96.7
No. 2	84.2	79.9[e]	75.9[e]	1.8[e] (0.32 to 3.50)	18.9	96.6
No. 3	84.4 84.4	82.4 82.3	79.4 79.3	1.2 1.3	16.0 16.0	96.6 96.6
Average	84.4	82.4	79.4	1.3	16.0	96.6
No. 4	84.8 83.8	82.0	80.2 80.2	1.2 1.0	15.9	97.3
Average	84.3		80.2	1.1		
No. 5	84.4	82.8	78.7	1.2 1.4 1.9 1.8 1.0	16.2	97.1
Average	....	......	......	1.5		
No. 6	84.2 84.0	82.2 82.3 82.4	79.3	1.2 1.3	15.8	96.4
Average	84.1	82.3		1.3		
No. 7	85.7[a, e]	....	80.8	0.25 0.25[e]	17.1	98.15
Average	....	......	......	0.25		
No. 8	83.3 83.3[e]	81.1	78.4 78.6	1.8 1.8[b]	14.9[e] 14.7	95.1[e]
Average	83.3		78.5	1.8	14.8	
No. 9	83.8[c] 84.4[d] 84.0 84.4 84.1 84.4	82.7 83.0 82.7	74.6[e] 74.3 74.5	3.8[e] 3.9 4.0	18.0 18.1 17.9	96.3
Average {	84.0 84.4 84.2	82.8	74.4	3.9	18.0	
No. 10	85.6[e] 84.9	82.5 83.1	84.6[e]	4.86[e] 2.46 0.58	9.3[e]	96.53
Average	85.3	82.8		2.63		
Mean	84.3	82.3	79.7	1.38	16.8	96.8
Average Deviation from Mean	0.15	0.6	1.4	12.7	5.4	0.43

[a] Titrated with $K_2Cr_2O_7$ in CO_2 atmosphere.
[b] Titrated with $KMnO_4$.
[c] Titration.

TABLE I.—*Continued.*

SAMPLE No. 6

Cooperator	Total Copper, per cent	Old Cuprous Oxide, per cent	New Cuprous Oxide, per cent	Copper, per cent	Cupric Oxide, per cent	Total,[f] per cent
No. 1	87.1	98.2	97.5	0.16	0.39	98.05
No. 2	87.6	97.2	95.9[e]	0.60[e] (0.60 to 0.60)	2.28	98.78
No. 3	87.5 87.4	97.8 97.7	97.3 97.3	0.17 0.16	1.16 1.18	98.63 98.64
Average	87.5	97.8	97.3	0.17	1.17	98.64
No. 4	87.4 88.0	98.1 98.4 97.8 97.4	98.8 98.7 97.7 97.6	0.06 0.06 0.11 0.08	1.10 1.10	99.96 98.91
Average	87.7	97.9	98.2	0.08	1.10	99.44
No. 5	87.3 87.3	98.6	98.0	0.15 0.17	0.30	98.45
Average	87.3			0.16		
No. 6	87.1 87.3	97.6 97.7	97.9	0.08 0.08	0.09	98.07
Average	87.2	97.7		0.08		
No. 7	87.3[a]	....	97.2	0.06 0.06 0.06	1.06	98.32
Average	....	....	......	0.06		
No. 8	88.3[e] 88.3[e]	96.9	98.2 97.8	0.26 0.28[b]	1.18 1.60	99.64 99.68
Average	88.3		98.0	0.27	1.39	99.66
No. 9	87.3[e] 87.6[d] 87.1 87.6 87.4 87.6	100.15[e] 100.03 100.15	99.19 99.37 99.37	0.16 0.16 0.16	negative negative negative	99.47
Average {	87.3 87.6 87.5	100.11	99.31	0.16		
No. 10	88.2 88.6	97.4 98.0	99.0	0.11 0.09	0.39	99.49
Average	88.4	97.7		0.10		
Mean	87.4	97.8	98.0	0.14	0.82	98.84
Average Deviation from Mean	0.2	0.38	0.5	36	61	0.5

[d] Electrolytic.
[e] Not used in any calculation of averages or deviations.
[f] Values in this column are the totals of the values under the columns for new cupric oxide, copper, and cuprous oxide.

type used for the determination of carbon in steel by direct combustion).[a] Place the boat at the center of the combustion tube maintained at a temperature of 1000 C. A current of pure dry air drawn through the tube sweeps the evolved moisture through a train of absorption tubes containing sulfuric acid or dry calcium chloride. The weight increase of the absorption tube represents the "combined water" (including moisture). Report the results as combined water.

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[a] Refer to Blair, "Chemical Analysis of Iron," Fig. 63, p. 138.

NOTE 1.—Loss on ignition of the pigment does not suffice for the determination of combined water in zinc chromates.

NOTE 2.—Traces of oil in the pigment should first be removed with ether.

In order to provide a method of test to accompany the new tentative Specifications for Aluminum Pigment Paste for Paint, as proposed by Subcommittee XV, new Methods of Sampling and Testing Aluminum Powder and Aluminum Paste, as appended hereto,[1] have been developed by this subcommittee and are recommended for publication as tentative.

This subcommittee further recommends the withdrawal of the Standard Method of Test for Determination of Polishing Lubricant in Aluminum Powder for Paints (Aluminum Bronze Powder) (D 306 – 31), since this method is now properly covered in the new tentative method being proposed.

Consideration has been given by this subcommittee to the various standards and tentative standards under its jurisdiction and it is recommended that those not mentioned in this report be continued in their present status for another year.

Consistency of Paint:

Progress is reported by the Work Committee, composed of Messrs. D. L. Gamble, R. H. Sawyer, A. E. Jacobsen, and G. G. Sward, in its study of methods for determining the consistency of paint.

Respectfully submitted on behalf of the subcommittee,

E. F. HICKSON,
Chairman.

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[1] See p. 835.

REPORT OF SUBCOMMITTEE XV ON SPECIFICATIONS FOR PIGMENTS DRY AND IN OIL WHEN MARKETED IN THAT FORM

During the past few years there has been marked and important progress in the manufacture of pigments. New pigments of outstanding value have been developed and the older varieties have been improved, especially in physical properties, to make them better adapted to specific uses.

This subcommittee has, since the last annual meeting, given detailed attention to bringing its specifications into step with the latest developments in industry, and the formulation of new specifications where required. In consequence, it recommends for publication as tentative, Specifications for Aluminum Pigment Paste for Paint, as appended hereto,[1] since industry has been able to produce an improved metallic aluminum pigment directly in the form of paste, rather than by combining previously made dry powder with a vehicle. Owing to the difference in manufacture and character of the product, it is considered desirable to cover this material by separate specifications.

Marked progress in the manufacture of aluminum pigment has resulted in this subcommittee recommending for publication as tentative, extensive revisions in the Standard Specifications for Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 – 31) in the form of new Tentative Specifications for Aluminum Powder for Paint (Aluminum Bronze Powder) as appended hereto.[1]

Recommendation for publication as tentative is also made in the case of Specifications for C. P. Para Red Toner, as appended hereto.[2] Although para red is used to a considerable extent in reduced form, many consumers now buy the pure toner, and in consequence this specification for pure red pigment is now offered.

The subcommittee further recommends that the Specifications for C. P. Zinc Yellow (Zinc Chromate), as appended hereto,[3] be published as tentative. Some years ago, the use of zinc chromate yellow as a rust-inhibiting pigment became known, and has been employed to such an extent that these specifications have been prepared.

The subcommittee suggests the consolidation of specifications for pigments which are closely related, in order to provide for greater economy in publication and for more ready reference and comparison. Recommendation for publication as tentative is therefore made in the case of Specifications for Titanium Dioxide Pigments, as appended hereto,[4] comprising a consolidation with revisions of the present Standard Specifications for Titanium Barium Pigment (D 382 – 35), Titanium Calcium Pigment (D 383 – 35), Titanium Dioxide (D 384 – 36), and Tentative Specifications for Titanium-Magnesium Pigment (D 442 – 37 T). In addition, it is recommended that specifications be published as tentative for Zinc Sulfide Pigments as appended hereto,[4] also representing a consolidation with revisions of the present Standard Specifications for Lithopone (D 208 – 26), Zinc Sulfide Pigment (Barium) (D 385 – 36), Zinc Sulfide (D 386 – 36), and Tentative Specifications for Zinc Sulfide Pigment (D 443 – 37 T).

The subcommittee points out that basic carbonate white lead, semipaste in oil, is now practically out of the market, having been superseded by a semipaste containing a volatile thinner. It therefore recommends for immediate adoption the following revisions in the Standard Specifications for Basic Carbonate White Lead (D 81 – 34):[1]

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[1] See pp. 822 and 821.

[2] See p. 826.

[3] See p. 831.

[4] See pp. 829, 833.

Semipaste in Oil.—Delete throughout these specifications all reference to semipaste in oil.

Section 2 (a).—Change this section from its present form: namely,

> 2. (*a*) *Dry Pigment.*—The pigment shall have a composition corresponding approximately to the formula $2PbCO_3 \cdot Pb(OH)_2$. It shall be free from impurities and shall meet the requirements given in Section 3 (*a*) and (*b*).

to read as follows:

> 2. (*a*) *Dry Pigment.*—The pigment shall be free from adulterants and shall contain not more than traces of impurities incident to well-controlled manufacture of high-grade basic carbonate white lead.

Section 3 (b).—Change this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*b*) Dry Pigment.—The pigment shall conform to the following requirements:

	MAXIMUM	MINIMUM
Lead carbonate, per cent	75.0	65.0
[Total impurities, including moisture, per cent]	[2.0]	[....]
Moisture and other volatile matter, per cent	*0.7*	....
Other impurities, per cent	*1.0*	....
Coarse particles retained on a No. 325 sieve, per cent	1.0	....

This subcommittee points out that in the specifications for pure and for reduced chrome green, the exact meaning of the item in Section 3 (*b*), requiring 70 per cent of the lead to be in the form of chromate, is not sufficiently clear. The following modification in wording, which will involve no change in composition of the pigment and may therefore be considered an editorial revision, is accordingly presented in the Standard Specifications for Pure Chrome Green (D 212 – 27),[2] and for Reduced Chrome Green (D 213 – 27):[2]

Section 3.—Change the first line of the table following Paragraph (*b*) of this section from its present form: namely,

> Percentage of total lead present in the form of chromate, minimum 70

to read as follows:

> Of the total lead (calculated as metallic lead, Pb) present in all forms in the pigment, at least 70 per cent (also calculated as metallic lead, Pb) shall be present in the form of chromate ($PbCrO_4$).

A 97 per cent grade of red lead is now largely sold and is the grade generally used for making paste. The subcommittee has accordingly prepared new Tentative Specifications for Red Lead, as appended hereto,[3] which are recommended for publication as a tentative revision of the Standard Specifications for Red Lead (D 83 – 31).

In the case of commercial para red, there has been considerable change, since calcium carbonate is now employed as the usual base in the preparation of this pigment, instead of barium sulfate. New Tentative Specifications for Reduced Para Red, as appended hereto,[3] are therefore proposed as a tentative revision of the Standard Specifications for Commercial Para Red (D 264 – 28).

This subcommittee recommends the adoption as standard of the Tentative Specifications for Basic Sulfate White Lead (D 82 – 37 T)[4] to replace the existing Standard Specifications D 82 – 24,[5] with the following minor revisions:

Section 1.—Change the second sentence of the Scope clause to read as follows by the addition of the italicized words and the omission of those in brackets:

> The pigment may be purchased in the dry form or [ground in oil to form a paste] *as a paste in oil.*

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 602.

[2] 1936 Book of A.S.T.M. Standards, Part II, pp. 570, 572.

[3] See pp. 827, 824.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 838; also 1937 Book of A.S.T.M. Tentative Standards, p. 658.

[5] 1936 Book of A.S.T.M. Standards, Part II, p. 604.

Section 2.—Change Paragraph (*b*) to read as follows by the omission of the words in brackets:

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with [pure raw or refined] linseed oil.

The adoption as standard is recommended in the case of the Tentative Specifications for Blue Lead; Basic Sulfate (D 405 - 35 T)[1] with the following minor revision:

Section 1.—Change the second sentence of the Scope clause to read as follows by the addition of the italicized words and the omission of those in brackets:

It may be purchased in the dry form or [ground in oil to form a paste] *as a paste in oil.*

During the coming year, the remaining pigment specifications under the jurisdiction of this subcommittee will be given a similar review, so that all of the standards for pigments will be entirely correct and up-to-date prior to the publication of the 1939 Book of A.S.T.M. Standards.

Respectfully submitted on behalf of the subcommittee,

H. E. SMITH,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 873; also 1937 Book of A.S.T.M. Tentative Standards, p. 657.

REPORT OF COMMITTEE D-2
ON
PETROLEUM PRODUCTS AND LUBRICANTS

Committee D-2 on Petroleum Products and Lubricants held three regular meetings during the past year (in June at New York, N. Y., in January at Detroit, Mich., and in March in New York, N. Y.).

During the year the following changes in subcommittees and technical committees have been made: Subcommittee I on Corrosion Test for Lubricating Oils has been transferred to Technical Committee B on Lubricants as a new Section V; Subcommittee XI on Turbine Oils has been discontinued; Technical Committee C on Fuel Oils (Including Diesel Fuel) has been discontinued and two new technical committees have been created, namely, Technical Committee E on Burner Fuel Oils and Technical Committee F on Diesel Fuel Oils.

The following revisions of American standards and American tentative standards have been approved by the American Standards Association, on the recommendation of Sectional Committee Z11 on Petroleum Products and Lubricants, to bring these standards into conformity with the revisions in the A.S.T.M. standards approved at the 1937 annual meeting:

Title	A.S.T.M. Designation	A.S.A. Number
American Tentative Standards		
Method of Test for Knock Characteristics of Motor Fuels....	D 357 - 37 T	Z11.37 - 1937
Viscosity-Temperature Charts for Liquid Petroleum Products	D 341 - 37 T	Z11.39 - 1937
American Standards		
Methods of Analysis of Grease..	D 128 - 37	Z11.16 - 1937
Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer....................	D 287 - 37	Z11.31 - 1937
Method of Test for Melting Point of Paraffin Wax.......	D 87 - 37	Z11.4 - 1937

During the year Committee D-2 presented to the Society, through Committee E-10 on Standards, a new Tentative Method of Test for Sediment in Fuel Oil by Extraction (D 473 - 38 T) and a revision of the Tentative Specifications for Fuel Oils (D 396 - 34 T). These recommendations were accepted[1] by Committee E-10 on April 27, 1938, and the new test method and revised specifications will appear in the 1938 *Proceedings*.[2]

Section VI on Acid Heat (L. C. Beard, Jr., chairman) of Technical Committee A on Gasoline has reported the data in the following table obtained by the use of the proposed Tentative Method of Test for Acid Heat of Gasoline, which method is being recommended for publication as tentative as stated below:

Laboratory	Acid Heats on Three Samples of Gasoline		
	Sample 5	Sample 6	Sample 7
1........................	43 F.	79 F.	122 F.
2........................	46 F.	70 F.	120 F.
3........................	41 F.	72 F.	108 F.(?)
4........................	46 F.	77 F.	128 F.
5........................	44 F.	76 F.	122 F.
6........................	43 F.	76 F.	114 F.
Mean.................	43.8 F.	75 F.	121.2 F.[a]
Maximum deviation from mean, per cent.........	6	7	6

[a] Omitting value from Laboratory 3.

Technical Committee F on Diesel Fuel Oils has recommended for publication as information a Proposed Method of Test for Ignition Quality for Diesel Fuels, and changes in the Diesel-Fuel-Oil Classification previously published. These appear in Appendices I and II to this report.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee D-2 reported the following results of the letter ballot vote of a total of 60 ballots returned from a committee membership of 78: D 473 - 38 T, affirmative 52, negative 1, ballots marked "not voting" 7; D 396 - 34 T, affirmative 42, negative 8, ballots marked "not voting" 10.

[2] See pp. 885 and 856.

The voting membership of Committee D-2 now consists of 36 producers, 29 consumers, and 13 general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

The committee recommends that the following methods of test and specifications be accepted for publication as tentative, as appended hereto:[1]

Tentative Method of Test for Acid Heat of Gasoline, proposed by Technical Committee A on Gasoline (C. B. Veal, chairman),

Tentative Method of Test for Ash Content of Petroleum Oils,

Tentative Method of Test for Unsulfonated Residue of Plant Spray Oils, proposed by Subcommittee XVII on Plant Spray Oils (J. B. Terry, chairman), (published for information last year and revised in accordance with the suggestions received), and

Tentative Specifications for Stoddard Solvent, proposed by Technical Committee D on Stoddard Solvent (L.E. Jackson, chairman).

Revisions of Tentative Standards:

The committee recommends revisions of five tentative standards, as follows:

Tentative Method of Test for Knock Characteristics of Motor Fuels (D 357 - 37 T).[2]—The revision of this method, recommended by Technical Committee A on Gasoline (C. B. Veal, chairman), represents essentially an editorial clarification and amplification. The method in its revised form is appended hereto.[3]

Tentative Method of Test for Expressible Oil and Moisture in Paraffin Waxes (D 308 - 29 T).[4]—The following editorial addition to this method, as recommended by Subcommittee III on Paraffin Wax (L. C. Beard, Jr., chairman), is a needed amplification of the specifications for the cloth used in the test:

Section 7.—Change this section from its present form: namely,

> 7. *Cloth.*—The cloth shall be a white or colored "silesia" or "duretta" or similar tightly-woven cloth free from nap. The cloth shall be accurately cut in disks 3.50 in. in diameter.

to read as follows:

> 7. *Cloth.*—The cloth shall be a clean, white, tightly-woven cotton fabric conforming to the following requirements:

Threads per inch in warp........	100 to 110
Threads per inch in filling.......	60 to 65
Weave........................	twill
Weight per square yard, oz......	4.7 to 4.9
Sizing material................	none

> These specifications can be met in a "silesia" or "duretta" or similar fabric. The cloth shall be accurately cut in disks 3.50 in. in diameter.

Tentative Method of Test for Penetration of Greases and Petrolatum (D 217 - 33 T).[5]—On the recommendation of Subcommittee IV on Grease (R. R. Matthews, chairman), the method has been rewritten to include a revised description of the penetrometer and a new sketch. The method in its revised form is appended hereto.[6]

Tentative Method of Test for Vapor Pressure of Petroleum Products (Reid Method) (D 323 - 37 T).[2]—The following additions are recommended by Subcommittee XXII on Natural Gasoline (G. G. Oberfell, chairman) as an improvement in the method:

Section 1.—Change the second sentence of the note following this section to read as follows by the addition of the italicized figure:

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[1] See pp. 862, 865, 887, and 859.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 879, 888 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 728, 756.

[3] See p. 871.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol 29, Part I, p. 682 (1929); also 1937 Book of A.S.T.M. Tentative Standards, p. 740.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 756 (1933); also 1937 Book of A.S.T.M. Tentative Standards, p. 745.

[6] See p. 866.

Sections 10 to 15, inclusive, shall be followed for products in the first group, and Sections 10, *13*, 21, and 22 for products in the second group.

Section 2 (e).—Add a new note following this paragraph to read as follows:

NOTE.—In determining capacities for the apparatus shown in Fig. 1 (*b*), the capacity of the gasoline chamber shall be considered as that below the gate-valve closure. The volume above the gate-valve closure including the portion of the coupling permanently attached to the gasoline chamber shall be considered as a part of the air-chamber capacity.

Section 3 (b).—At the end of this paragraph add a new sentence to read as follows:

When the "gage correction" (Section 18 (*h*)) exceeds 1 per cent of the scale range, the gage shall be considered inaccurate.

Section 6.—Add a new note following this section to read as follows:

NOTE.—As an alternate, the oil-tube thermometer having a range of 94 to 108 F. as prescribed in the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88) of the American Society for Testing Materials may be used.

Section 12 (b).—Change the first two sentences to read as follows by the addition of the italicized words:

(*b*) Sampling into Closed-Type Sample Containers.—Closed-type sample containers (Section 9) may be used for obtaining samples from closed vessels *by either of two methods, that is, purging with the gasoline being sampled or by water displacement. The water displacement method is preferable where the flow involved in the purging procedure may create a hazard.*

When the purging method is used, the inlet valve of the container shall be connected to the sampling line from the pressure vessel.

Add as a new paragraph under Section 12 (*b*) a description of the water-displacement method to read as follows:

When the water displacement method is used, the procedure shall be as follows: Previous to sampling, the container shall be completely filled with water which shall be maintained at a temperature equal to or lower than that of the gasoline to be sampled. When sampling, the top or inlet valve of the container shall be connected to the source of the sample as directly as possible, the connection being made while a small amount of the liquid to be sampled is flowing through the fittings comprising the connection. All valves on the inlet side of the container shall then be opened wide and the bottom or outlet valve opened slightly thus allowing the water to be displaced slowly by the sample entering the container. Flow shall be so regulated that there is no appreciable diminution of pressure in the container. As soon as gasoline discharges from the outlet, the outlet valve shall be closed, followed in succession by closure of the inlet valve and the valve on the sample tap. The container shall then be disconnected, taken to a safe locality and 20 to 30 per cent of its contents removed. The sample container shall then be promptly sealed for transportation to the point where the test is to be completed.

Section 15 (c).—Change to read as follows by the addition of the italicized word:

(*c*) With everything in readiness the chilled sample container shall be removed from the bath; the cap, stopper or plug shall be removed and the *pre-cooled* transfer connection immediately attached to the sample container.

Sampling Procedures for Products Having Vapor Pressures Over 26 lb.—Change the second paragraph of the explanatory material under this heading to read as follows by the addition of the italicized figure:

The complete method for products under this title comprises Sections 1 to 3, 5 to 7, 10, 21, 22, *13*, and 16 to 20, in the order listed.

Section 21.—Change Paragraph (*a*) to read as follows by the addition of the italicized words and the omission of those in brackets:

21. (*a*) The sample shall be obtained as described in [either] *one* of the following Paragraphs (*b*), [or] (*c*), *or (d)*. This operation fits between the steps described in Section 17 (d) and (e).

Change the heading of Paragraph (*b*) to read as follows by the addition of the italicized words:

(*b*) Sampling *Directly into Gasoline Chamber* by Immersion

Change the heading of Paragraph (*c*) to read as follows by the addition of the italicized words:

(*c*) Sampling *Directly into Gasoline Chamber* from Closed Vessels

Add the following as a new Paragraph (*d*):

(*d*) *Sampling into Closed-Type Sample Containers.*—Under conditions which render sampling directly into the gasoline chamber hazardous, the procedure outlined in Section 12 (*b*) shall be used, so that the sample may be kept until ready for testing. When ready to test, the closed-type sample container may be considered as a closed vessel and the sample obtained from it as prescribed in Paragraph (*c*) using water displacement to force the sample into the gasoline chamber and to maintain a pressure substantially in excess of the pressure in the tank at the time of sampling.

Tentative Methods of Test for Kinematic Viscosity (*D 445 – 37 T*).[1]—The following minor revisions are recommended by Subcommittee V on Viscosity (J. C. Geniesse, chairman):

Table I.—Change four of the dimensions of the FitzSimons' viscosimeter to read as follows by the addition of the italicized figures and the omission of those in brackets:

Over-all length, mm		300 to [340] *400*
Outside diameter	of bulb C, mm	10 to [14] *15*
	of bulb A, mm	20 to 30
Length of bulb A, mm		70 to [80] *95*
Inside diameter	of tubes 1 and 4, mm	8 to [10] *12*
	of tubes 2 and 3, mm	4 to [5] *6*
	of tube 5 (square shoulder), mm	10 to 15
	of tube 5 (spherical shoulder), mm	14 to 17

Section 3 (*b*).—Change the first sentence to read as follows by the addition of the italicized words and the omission of the words and figure in brackets:

(*b*) The viscosimeter shall be immersed in the bath [to within 5 cm. of the top] *so that bulb C is below the surface of the bath liquid* and *shall be* adjusted to a vertical position.

Section 7 (*d*).—Change to read as follows by the addition of the italicized words and the omission of the words and figure in brackets:

(*d*) After loading, the excess oil shall be wiped off the top of the viscosimeter and it shall then be placed in the constant temperature bath. It shall be immersed [in] *so that bulb A is below the surface of* the bath liquid [to within 5 cm. of the top].

Revisions of Standards:

The committee recommends for immediate adoption as standard, revisions in three standard methods of test, as indicated below, and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that these modifications may be referred to letter ballot of the Society:

Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (*D 86 – 35*).[2]—The following addition is recommended by Subcommittee VIII on Distillation (E. W. Dean, chairman):

Section 9.—Add a new paragraph at the end of the section to read as follows:

The sum of the volume collected in the cylinder at any specified temperature and the distillation loss may be recorded as the percentage evaporated at the temperature in question.

Standard Methods of Testing Gas Oils (*Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water*) (*D 158 – 28*).[3]—A revision of these methods, recommended by Subcommittee VIII on Distillation (E. W. Dean, chairman), consists of the deletion of references to tests other than the distillation test and a clarification and slight modification of the distillation procedure. The method in its revised form, entitled "Standard Method of Test for Distillation of Gas Oil and Similar Distillate Fuel Oils," is appended hereto.[4]

Standard Method of Test for Saponification Number (*D 94 – 36*).[5]—At the suggestion of Committee D-9 on Electrical Insulating Materials, Subcommittee XIII on Neutralization Number and Saponification (E. B. McConnell, chairman) has recommended that the Standard Method of Test for Saponification Number (D 94 - 36) and the Tentative Method of Test for Saponification Number of Electrical Insulating Oils (Modified Baader Method) (D 438 - 36 T) be combined into a new tentative method of test for saponification as appended hereto,[1] and that the two present methods be withdrawn.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 900 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 768.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 870.

[3] *Ibid.*, p. 913.

[4] This revised method was adopted as standard by the Society and appears in the 1938 Supplement to Book of A.S.T.M. Standards, p. 144.

[5] 1936 Book of A.S.T.M. Standards, Part II, p. 970.

The committee recommends that the revisions proposed in the following three standard methods of test be accepted for publication as tentative:

Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 36).[2]—The following tentative revision of this method is proposed by Subcommittee XXIII (L. C. Beard, Jr., chairman), to clarify the description of the procedure and to provide a method for obtaining a 10 per cent residuum:

Section 3.—Add the following new sentence at the end of the third paragraph of this section:

> If it is found impossible to meet the requirements for both flame and burning time, the requirement for burning time is the more important.

Section 4.—Letter the present section as Paragraph (*a*) and add a new Paragraph (*b*) to read as follows:

> (*b*) *Special Procedure for Light Distillate Oils Having Carbon Residues Less than 0.05 per cent, Such as No. 1 and No. 2 Fuel Oils.*—In the case of these oils, the carbon residue test shall be made on a 10 per cent residuum obtained by an adaptation of the distillation procedure in the Standard Method of Test for Distillation of Gas Oil and Similar Distillate Fuel Oils (A.S.T.M. Designation: D 158) of the American Society for Testing Materials with respect to Sections 8 (*b*) and 10, as follows:
>
> To receive the distillate, use the 200-ml. graduate, without cleaning, used to measure the initial sample.
>
> Maintain the condenser outlet at 32 to 40 F. (0 to 4.45 C.) throughout the distillation in the case of products having distillation end points below 600 F., (315 C.), and use the standard condenser temperatures 90 to 100 F. (32.2 to 37.8 C.) for products having end points above 600 F. (315 C.), or in those cases where waxy distillates are obtained.
>
> Carry out the distillation at the rate prescribed until exactly 178 ml. have been collected in the graduate, then discontinue the heating and allow the condenser to drain until 180 ml. (90 per cent of the charge to the flask) has been collected in the graduate. Replace the graduate with a small Erlenmeyer flask and catch any final drainage in this flask.
>
> To this Erlenmeyer flask add, while still warm, the residue left in the distillation flask and shake well.
>
> The contents of the Erlenmeyer flask then represent a 10 per cent residuum from the original product. While warm enough to flow freely, pour approximately 10 g. of the residuum into the weighed crucible to be used in the carbon-residue test. After cooling, determine the weight of the sample accurately and carry out the carbon-residue test in accordance with the standard method as given in Section 3. Report the percentage of carbon residue in the residuum as "carbon residue on 10 per cent residuum."
>
> NOTE.—It is important that a clean distillation flask be used for each test.

Section 5.—At the end of this section add a new sentence to read as follows:

> In the case of the carbon residue on 10 per cent residuum, duplicate determinations should differ by not more than 20 per cent from an average if the value is 0.10 per cent or higher. For lower values the deviations of individual determinations will be higher, increasing as the carbon residue decreases.

Standard Method of Test for Cloud and Pour Points (D 97 - 34).[3]—The addition of a section on Reproducibility of Results as a new Section 13 is proposed by Subcommittee XVI on Cloud and Pour Test (L. C. Beard, Jr., chairman) as follows:

> 13. *Reproducibility of Results.*—Individual results of the pour test on the same oil in any one laboratory may vary by 5 F. and in different laboratories by 10 F., although the average of three or more results in different laboratories should show a difference between averages no greater than 5 F. For oils tested by the special procedure described in Section

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[1] See p. 881.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 849.

[3] 1936 Book of A.S.T.M. Standards, Part II, p. 853.

12, reproducibility of this order cannot be expected, as these oils show anomalous pour points depending on the previous thermal history.[a]

[a] It is a recognized property of these oils that the temperature to which they have been subjected before testing influences their pour points. Although the lower pour points as determined by the special procedure will show approximately the reproducibility given above, yet the upper pour points will show greater variations depending on the previous thermal history of the oils. Further information on this subject is contained in *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, pp. 468 to 470 (1931), and Vol. 32, Part I, pp. 402 to 405 (1932).

Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 37).[1]—The following revision is proposed by Subcommittee II on Gravity (H. T. Bennett, chairman) to clarify the procedure for determining the gravity of crude petroleum:

Section 6 (b) and (c).—Change to read as follows by the addition of the italicized words and figures and the ommission of those in brackets:

(*b*) *Crude Petroleum or a Product Thereof* [A product] with *an* initial boiling point below 250 F. (121.1 C.) and an A.P.I. gravity below 70 *deg.* shall be cooled in the original closed container to a temperature of 65 F. (18.3 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum or a product thereof* [A product] having an A.P.I. gravity of 70 *deg.* or greater shall be cooled in the original closed container to a temperature of 35 F. (1.7 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum having an initial boiling point below 250 F. (121.1 C.) which has too high a pour point or is too viscous at 65 F. (18.3 C.) to permit an accurate hydrometer reading at 65 F. (18.3 C.) or below should be heated to the minimum temperature which will give sufficient fluidity to permit an accurate hydrometer reading.*

(*c*) The thermometer, hydrometer, and hydrometer cylinder shall be at approximately the same temperature as the *sample* [product] to be tested. Precaution shall be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing nonvolatile and nonviscous *samples* [oils] by choosing a temperature of test only slightly different from the room temperature. When volatile [products] *samples* (*those having initial boiling points below 250 F. (121 C.) and also those having A.P.I. gravities greater than 70 deg.*) are cooled, or viscous [products] *samples are* heated, the test cylinder shall be placed in a bath maintained at the *necessary* [a constant desired] temperature during the time of test. *In determining the gravity of any crude petroleum or product, the temperature of the surrounding medium should not differ from the temperature of the sample by more than 5 F. (2.8 C.).*

Adoption of Tentative Standard as Standard:

The committee recommends that the Tentative Method of Test for Color of Refined Petroleum Oil by Means of Saybolt Chromometer (D 156 – 34 T),[2] proposed by Subcommittee VI on Color (H. M. Hancock, chairman), be approved for reference to letter ballot of the Society for adoption as standard.

Adoption as Standard of Tentative Revision of Standard:

The committee recommends that the tentative revision published last year[3] of the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (D 88 – 36)[4] be further revised and referred to letter ballot of the Society for adoption as standard. The revision now being recommended is as follows:

Section 4 (c).—Change the note following this section to read as follows by the addition of the italicized sentence:

NOTE.—The plunger commonly supplied with the viscosimeter shall never be used on instruments maintained as standards. *In case the flash point is less than 50 F. above the temperature of test, the wetting operation should be omitted in order to avoid an increase in viscosity due to evaporation of a portion of the light fraction.*

Section 4 (d).—After the first sentence add a new sentence to read as follows:

In no case, however, shall the oil be preheated to a temperature above 50 F. below the flash point.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 121.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 895 (1934); also 1937 Book of A.S.T.M. Tentative Standards, p. 720.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 365, 1320 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1578.

[4] 1936 Book of A.S.T.M. Standards, Part II, p. 982.

Tentative Standards Continued as Tentative:

Five methods of test have been tentative for a period of three years or longer, without revision, as follows:

Tentative Methods of:

Test for Color of Lubricating Oils by Means of A.S.T.M. Union Colorimeter (D 155 – 34 T),
Test for Color of Petrolatum by Means of A.S.T.M. Union Colorimeter (D 218 – 34 T),
Test for Expressible Oil and Moisture in Paraffin Waxes (D 308 – 29 T),
Test for Neutralization Number of Petroleum Products and Lubricants (D 188 – 27 T), and
Test for Sulfur in Petroleum Oils by Lamp Method (D 90 – 34 T).

These methods may be revised before being adopted as standard as a result of plans for further work by the respective subcommittees. It is accordingly recommended that they be continued as tentative.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Test for Acid Heat of Gasoline	55	0	10
Test for Ash Content of Petroleum Oils	50	1	1
Test for Unsulfonated Residue of Plant Spray Oils[a]	46	1	18
Specifications for Stoddard Solvent	50	2	13
II. REVISIONS OF TENTATIVE STANDARDS			
Test for Knock Characteristics of Motor Fuels (D 357 – 37 T)[a]	48	1	16
Test for Expressible Oil and Moisture in Paraffin Waxes (D 308 – 29 T), editorial change	40	0	12
Test for Penetration of Greases and Petrolatum (D 217 – 33 T)	48	0	4
Test for Vapor Pressure of Petroleum Products (D 323 – 37 T)[a]	55	0	10
Test for Kinematic Viscosity (D 445 – 37 T)	59	0	6
III. REVISIONS OF STANDARDS			
Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 – 35), immediate adoption	49	0	3
Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water) (D 158 – 28), immediate adoption[a]	50	3	15
Test for Saponification Number (D 94 – 36)	46	0	6
Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 – 35)	61	0	4
Test for Cloud and Pour Points (D 97 – 34)	49	0	3
Test for Gravity of Petroleum and Petroleum Products (D 287 – 37)	50	0	2
IV. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Test for Color of Refined Petroleum Oil by Means of Saybolt Chromometer (D 156 – 34 T)	58	0	7
V. ADOPTION AS STANDARD OF TENTATIVE REVISION OF STANDARD			
Test for Viscosity by Means of Saybolt Viscosimeter (D 88 – 36)[a]	59	2	4

[a] Additional revisions in these methods presented at the annual meeting are recorded in the Summary of Proceedings, pp. 21 to 24, together with the results of the confirming letter ballot in the committee.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 78 voting members, with the results shown in Table I.

The election of officers for the ensuing term of two years resulted in the reelection of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 78 voting members; 65 members returned their ballots, of whom 62 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

T. A. BOYD,
Chairman.

R. P. ANDERSON,
Secretary.

APPENDIX I

PROPOSED METHOD OF TEST FOR IGNITION QUALITY OF DIESEL FUELS[1]

This is a **proposed method** and is published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

1. *Scope.*—This method of test is intended for determining the ignition quality of Diesel fuels in terms of an arbitrary scale of cetane numbers.

2. *Cetane Number.*—The cetane number of a Diesel fuel is defined by and is numerically equal to the percentage by volume of cetane in a mixture of cetane and α-methylnaphthalene which the fuel matches in ignition quality when compared by the procedure specified herein. Thus, by definition, α-methylnaphthalene has a cetane-number rating of zero and cetane of 100. Cetane number is reported to the nearest whole number.

APPARATUS

3. *Apparatus.*—The ignition-quality testing unit described in this section shall be used without modification. It shall be known as the "C.F.R. Diesel-Fuel Testing Unit."[2] The apparatus shall consist of a continuously-variable-compression engine, together with instrument panel, base, and suitable loading and accessory equipment, as follows:

(*a*) *Engine.*—Continuously-variable-compression, one-cylinder, with dimensions as follows:

Bore, in	3.25
Stroke, in	4.50
Displacement, cu. in	37.4
Turbulence combustion chamber:	
bore, in	1.625
length, in., adjustable	0.375 to 2.750
Valve-port diameter, in	1.187
Connecting-rod bearing:	
diameter, in	2.25
length, in	1.625
Front main bearing:	
diameter, in	2.25
length, in	2.00
Rear main bearing:	
diameter, in	2.25
length, in	4.25
Piston pin, floating, diameter, in	1.25
Connecting rod, length, center to center, in	10.00
Timing-gear face, in	1.00
Piston rings, number	5
Exhaust pipe, diameter, in	1.25
Weight of engine, lb. (approximate)	475
Weight of complete unit, lb. (approximate)	1375

(*b*) *Crankshaft.*—Fully machined, heat-treated, and counter-balanced.

(*c*) *Crankcase.*—Cast iron.

(*d*) *Connecting Rod.*—Rifle-drilled, S.A.E. No. 1045 steel, heat-treated, bearing alloy cast directly into big end.

(*e*) *Main Bearings.*—Renewable sleeve bushings, babbitt-lined.

(*f*) *Valves.*—Silcrome.

(*g*) *Push Rods.*—Mushroom type with lock-nut adjustment.

(*h*) *Cylinder.*—Cast-iron alloy, bored and honed, Brinell hardness 220 ± 20.

(*i*) *Cylinder Head.*—Detachable variable-compression high-turbulence.

(*j*) *Cooling System.*—Evaporative.

(*k*) *Lubrication.*—Pressure feed to main, connecting-rod, piston-pin and camshaft bearings, to idler-gear stud and gears, and to valve rocker arms.

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[1] Under the standardization procedure of the Society, this proposed method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

This method originated in the Automotive Diesel Fuels Division of the Cooperative Fuel Research Committee, which is composed of representatives of the American Petroleum Institute, the Automobile Manufacturers Association, the Society of Automotive Engineers, Inc., and the National Bureau of Standards.

[2] At present the sole authorized manufacturer of the C.F.R. Engine is the Waukesha Motor Co., Waukesha, Wis. Other manufacturers may be approved in the future, but testing laboratories should not purchase testing units except from the Waukesha Motor Co. without ascertaining whether such units have been approved. Inquiries in this connection should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 50 West Fiftieth Street, New York, N. Y.

(*l*) *Oil Heater and Thermometer.*—Electric heater in base to bring oil to operating temperature quickly, and a thermometer on the instrument panel to indicate when equilibrium temperature has been reached.

(*m*) *Air Heater and Thermometer.*—Electric heater mounted on intake silencer to maintain constant air-inlet temperature, and a thermometer at base of silencer to indicate this temperature.

(*n*) *Water Heater and Thermometer.*—Electric heater in cooling-water line between outlet of condenser and inlet to cylinder jacket to bring water to operating temperature quickly, and a thermometer between condenser and heater to indicate this temperature.

(*o*) *Injection System.*—This system shall consist of the following parts as furnished with the engine:

(*1*) Injector pump, Bosch specification PE1B50A 302/3S97, port closing at 0.075 to 0.090 in. lift from base circle.

(*2*) Injector, Bosch specification DN – 30S3.

(*3*) Fuel line (tank to pump), $\frac{3}{8}$-in. copper tubing, bottom of fuel tank to be 25 ± 1 in. above pump inlet.

(*4*) The injection line, $\frac{1}{4}$ in. O.D., $\frac{1}{8}$ in. I.D., and 36 in. in length.

(*5*) Vertical open riser with measuring burette located on pump sump outlet.

(*p*) *Instrumentation.*—The ignition quality is measured by the coincident-flash fixed-delay method using neon lights which are located on the periphery of the flywheel and are operated by contact points on the combustion and injection indicators. The necessary instrumentation consists of the following parts:

(*1*) The combustion indicator which mounts in a tapped hole ($\frac{7}{8}$ in. by 18 threads per inch) in the combustion chamber and is equipped with a spring-steel indicator diaphragm 0.543 ± 0.003 in. in diameter and 0.015 ± 0.0005 in. in thickness. The contact points are mounted on bronze leaf springs 0.021 ± 0.0005 in. in thickness. Graduated spring-tension adjusting screws are provided. In addition, a graduated gap-adjusting screw is provided with a spring cushion plunger to protect the contact points against overloading as the result of combustion pressures.

(*2*) The injection indicator, which utilizes contact-point assembly parts similar to the combustion indicator, with brackets for attachment to permit operation of the contact points by movement of the injector valve.

(*3*) The neon light mount which carries two $\frac{1}{4}$-watt, 110-v., neon bulbs located behind an aperture plate with 13 deg. spacing between openings.

(*4*) The sight tube and top dead center reference mark with brackets.

(*5*) Flywheel slip rings and brush holders with necessary brackets and wiring for the neon-light support.

(*6*) A 110-v. d-c. generator to supply current for the injection and combustion indicators. This is belt-driven from the power-absorbing unit described under Paragraph (*q*). The voltage is controlled to 115 ± 5 v. by means of a field-rheostat located on the instrument panel.

(*q*) *Power-Absorbing Unit.*—The engine is connected by V-type belts to an electric generator which preferably should be an induction motor with synchronous characteristics, but may be any electric generator capable of maintaining proper operating conditions. In most cases the electric generator will act as a starting motor to crank the engine, but if a direct-current generator is used and no outside source of current is available, the engine may have to be cranked by hand.

(*r*) *Panel.*—A control panel with starter switches, heater switches, and oil-temperature and pressure gages is included as part of the unit.

(*s*) *Base.*—The complete unit is mounted on a cast-iron base.

4. *Foundation.*—The foundation shall be of concrete, at least 15 in. in height above the floor level, resting, if possible, directly on the ground. Otherwise, special provision must be made to eliminate vibrations that may influence ratings and the manu-

facturer should be consulted. For convenience in operation, the foundation should be located at least 2 ft. from any wall. Dimensions are furnished with the apparatus.

5. *Reference Fuels.*—The primary reference fuels[1] shall be normal cetane and α-methylnaphthalene. Secondary reference fuels,[2] suitably calibrated against these primary reference fuels, are normally used in actual testing.

PROCEDURE

6. *Standard Operating Conditions.*—The engine shall be run under the following standard conditions:

(*a*) *Engine Speed.*—Constant, 900 ± 9 r.p.m.

(*b*) *Jacket Temperature.*—Constant within ± 1 F. (0.6 C.) and at a temperature between the limits of 209 and 215 F. (98 and 102 C.).

(*c*) *Cooling Liquid.*—Distilled water or rain water, or ethylene-glycol solution when necessary at high altitude.

(*d*) *Crankcase Lubricating Oil.*—S.A.E. 30.

NOTE 1.—The viscosity range of crankcase lubricating oil, S.A.E. 30, is from 185 to 255 sec. when determined on the Saybolt Universal viscosimeter at 130 F. (54.4 C.), in accordance with the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88) of the American Society for Testing Materials.[3]

(*e*) *Oil Pressure.*—25 to 30 psi. under operating conditions.

(*f*) *Oil Temperature.*—The electric oil heater shall be used only to raise the oil temperature rapidly to the equilibrium operating temperature, 120 to 150 F. (49 to 65 C.), normal operation maintaining the equilibrium thereafter. By "equilibrium" is meant that steady temperature attained by the oil upon continuous operation of the engine without the use of the heater.

(*g*) *Valve Clearances, Cold.*—Intake 0.008 in., exhaust 0.010 in.

(*h*) *Injection Advance.*—13 deg. b.t.d.c. for rating and 5 deg. (±2 deg.) b.t.d.c. for combustion contact setting.

(*i*) *Injection Pressure* (injector opening pressure).—1500 ± 50 psi. (106 ± 4 kg. per sq. cm.).

(*j*) *Injection Quantity.*—13.0 ± 0.5 ml. per minute, to be checked on each test sample and reference fuel blend.

(*k*) *Injection Pump Setting.*—See Paragraph 3 (*o*) for injection system specifications.

(*l*) *Injector Cooling-Water Jacket Temperature.*—100 ± 5 F. (38 ± 3 C.).

(*m*) *Exhaust Pipe.*—A separate exhaust pipe shall be used for each engine. It shall be made of pipe of not less than $1\frac{1}{4}$ in. in inside diameter having a maximum of two ells and a total length not to exceed 20 ft. The use of a short straight-through muffler with passage $1\frac{1}{4}$ in. in diameter is permissible.

(*n*) *Air-Inlet Temperature.*—The air-inlet temperature shall be maintained at 150 ± 2 F. (66 ± 1 C.).

(*o*) *Clearance Volume.*—The clearance volume measured to the top face of the combustion indicator hole shall be 72 ± 0.5 ml. with the engine at top dead center. At this volume the micrometer should be set to read 2.000 in. The compression ratio is given by the equation:

$$\text{C.R.} = \frac{18}{L} + 1$$

where L = the length of the combustion chamber in inches as measured by the micrometer.

7. *Starting and Stopping the Engine.*—While the engine is being turned over by electric motor, the fuel by-pass valve on the injector shall be closed and the compression ratio increased until the engine begins to fire. To stop the engine, the fuel by-pass valve on the injector shall be opened and the electric motor then switched off.

8. *Checking Injection Pump for Port Closing.*—The pump-plunger port should close when the plunger has traveled up

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[1] Normal cetane is available from E. I. duPont de Nemours and Co., Wilmington, Del., and α-methylnaphthalene, from the Reilly Tar and Chemical Co., Indianapolis, Ind.

[2] High-cetane secondary reference fuel known as "Shell high-cetane reference fuel" is available from the Shell Petroleum Corp., Wood River, Ill. Low-cetane secondary reference fuel, a mixture of α- and β-methylnathphalenes, is available from the Reilly Tar and Chemical Co., Indianapolis, Ind.

[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 148.

0.075 to 0.090 in. from the base circle of the cam. This setting is important as it influences the injection rate. This adjustment is made in the factory and should not require resetting unless it has been tampered with. To check the port closing the following operations shall be made:

(*a*) Remove the discharge valve and spring from the top of the pump and replace the discharge valve clamp nut with injection tube arranged conveniently for blowing into.

(*b*) Submerge the end of the fuel drain line in oil.

(*c*) Remove the pump cover, open the fuel pump rack to its wide open position, and turn the engine until the pump plunger starts up. Then blow on the tube and at the same time turn the engine slowly until bubbles disappear at the end of the fuel drain line which is submerged in oil. When bubbles cease, it indicates that the port has just closed. Determine this point carefully by several trials and mark the flywheel.

(*d*) Remove the tube used for blowing into the pump and insert a pin in the discharge valve hole and resting on the top of the plunger. Arrange a dial indicator resting on the pin to indicate the pump plunger lift. With the plunger at the bottom of its stroke and the dial gage set on zero, turn the engine until the reference mark previously placed on the flywheel to indicate point of port closing registers. Then read the dial gage which will indicate the pump plunger lift from the base circle when the port closes. This should be 0.075 to 0.090 in. Any deviation from this value can be adjusted by turning the pump-plunger adjusting screw. After making an adjustment a new reference mark must be established on the flywheel as outlined in Paragraph (*c*).

9. *Injection Pressure Setting.*—The injection-pump cover shall be removed and, with injection-line pressure gage connected and injector arranged to spray into the air, the pump plunger shall be operated with a screw driver used as a lever. With the pressure gage set at 1500 psi. (106 kg. per sq. cm.), the pressure on the injector spring shall be adjusted until equal quantities of fuel spray from the gage and the injector. The opening pressure of the injector will then be the same as indicated on the gage.

10. *Injection Indicator Contact Setting.*—The injection indicator contact setting shall be made as follows:

(*a*) Adjust injection contact mounting bracket until there is about $\frac{1}{32}$-in. clearance between the spring leaf and the injector pin.

(*b*) Screw out center adjusting screw.

(*c*) Adjust the lower leaf until it just touches the end of the injector pin. Then apply tension by turning the screw down one more complete turn.

(*d*) Adjust the upper leaf by turning down the upper leaf adjusting screw until the contact points touch. Be sure that the points touch as a result of the leaf-spring tension and not because of force applied downward by the adjusting screw. If the latter should be the case, it is necessary to remove the spring and bend it slightly downward at the outer end. The adjusting screw should then be turned up one complete turn from this position.

(*e*) Adjust the bumper-spring tension in the center adjusting screw by turning down the bumper-spring adjusting screw as far as it will go.

(*f*) Adjust the contact-point gap, with the engine running normally and the neon indicating switch closed, by screwing down the center adjusting screw until the neon tube just makes a solid band of light around the flywheel. Then turn back the center adjusting screw two divisions (0.002 in.) and lock by means of clamping screws.

11. *Combustion Indicator Contact Setting.*—The combustion indicator contact setting shall be made as follows:

(*a*) Screw out center adjusting screw.

(*b*) Adjust the lower leaf until it just touches the end of the combustion indicator pin. Then apply tension by turning the screw down one more complete turn.

(*c*) Adjust the upper leaf by turning the upper leaf adjusting screw down until the contact points just touch. Be sure that the points touch as a result of the leaf-spring tension and not because of force applied downward by the adjusting screw. If the latter should be the case, it is necessary to remove the spring and bend it slightly downward at the outer end. The adjusting screw should then be turned up one complete turn from this position.

(*d*) Adjust the bumper-spring tension in the center adjusting screw by turning down the bumper-spring adjusting screw as far as it will go.

(*e*) Make preliminary contact-point adjustment by screwing down the center adjusting screw until there is a gap of approximately 0.010 in.

12. *Final Combustion Indicator Contact Setting.*—The final combustion indicator contact setting shall be made as follows:

(*a*) Carry out this setting for each test fuel.

(*b*) Adjust compression ratio until engine fires normally on sample fuel. This is about two ratios above the lowest operating ratio without misfire.

(*c*) Close neon indicating switch.

(*d*) Check injection angle to make sure it is 13 deg. b.t.d.c. with engine operating on sample fuel. The injection neon tube is displaced 13 deg. on the flywheel to make it flash at t.d.c. when injection actually occurs at 13 deg. b.t.d.c.

(*e*) Make preliminary compression-ratio adjustment until combustion, as determined by the "hook" method, occurs at top dead center. The "hook" method is as follows:

The combustion indicator pin is restrained to follow the diaphragm by means of a leaf spring. The spring pressure is such that for accelerations up to the maximum rate of pressure rise due to compression pressure the pin is held on the diaphragm. Thus the gap between the indicator pin and the upper contact is an accurate measure of the deflections of the diaphragm. The position of the diaphragm is a function of the crank angle of the piston and thus the position of the upper contact pin determines the angular position of the neon flash.

Near the flat top of the compression pressure diagram, therefore, a very slight contact point movement indicates a considerable flywheel angular movement and the neon tube flash position is very sensitive to the contact gap adjustment. But when combustion occurs the very steep pressure rise of the diagram makes the neon flash position very insensitive to contact gap adjustment. The transition from the sensitive to insensitive gap adjustment range is called the "hook" point.

The contact adjustment procedure is to turn up the upper contact adjusting screw from a closed position until the rapid movement of the flash suddenly changes to a slow movement for a given constant angular motion of the contact adjusting screw. This is the "hook" point and the position of the neon flash indicates the start of combustion.

(*f*) For final-combustion contact-point adjustment retard injection timing to 5 deg. b.t.d.c.

(*g*) Adjust upper contact until two flashes of the neon bulb on the flywheel are just seen, one at t.d.c. from compression pressure and the other about 10 deg. a.t.d.c. from combustion.

(*h*) Raise upper contact one-half division (approximately 0.0005 in.) on adjusting screw where only one flash from combustion will be seen.

13. *Rating.*—(*a*) The injection shall be reset to the rating position of 13 deg. b.t.d.c., which will make the injection flash appear at t.d.c.

(*b*) The final compression ratio shall be adjusted so as to give coincidence of the injection and combustion neon flashes. The combustion chamber length shall then be recorded. It is advisable to check combustion contact point setting by moving injection timing and watching whether or not the combustion and injection flashes move and are still coincident. If so, the setting is correct.

(*c*) From the combustion chamber length, recorded when the sample fuel has been adjusted, to operate at standard conditions with 13 deg. delay period, the cetane number of the unknown sample shall be estimated and two reference fuel blends selected, differing by not more than eight cetane numbers, which will bracket the unknown sample. When two reference fuels have been found, one of which has a longer delay period and the other a shorter delay period than the sample, alternate readings shall be taken by adjustment of the combustion chamber length until the neon light flashes coincide at t.d.c. Alternate readings between the sample and reference fuels shall be taken in the following order: Sample, reference fuel No. 1, reference fuel No. 2, sample, reference fuel No. 1, and reference fuel No. 2. After changing from one fuel to another, 5 min. shall be allowed before taking a reading to insure complete flushing of the injection system. The average combustion-chamber lengths obtained from the above series shall be used in calculating the cetane number.

14. *Calculation.*—The cetane number of the fuel shall be calculated by interpolation from relative combustion-chamber lengths as obtained in Section 13 (*c*). The cetane number shall be reported to the nearest whole number. When the calculated value falls exactly half-way between two whole numbers, the nearest even number shall be reported.

MAINTENANCE

15. *Maintenance.*—The following points are important in maintenance technique:

(*a*) Injector should be inspected and cleaned at least every 8 hr. of operation.

(*b*) Compression plug should be cleaned when it becomes tight due to carbon.

(*c*) Special care should be exercised in keeping the fuels and fuel system clean.

(*d*) A general overhaul, including the grinding of valves, cleaning of piston and rings, and cylinder and cylinder head, should be made every 75 hr. of operation.

(*e*) Periodic inspection of connecting-rod and main bearings is recommended.

APPENDIX II

DIESEL-FUEL-OIL CLASSIFICATION

Manufacturers and users of Diesel engines, as well as petroleum refiners and distributors, have long felt the need for some classification differentiating types of fuel oils suitable for Diesel engines. The classification shown in Table I, covering three grades of oil, is offered by Technical Committee E on Diesel Fuel Oils of Committee D-2 on Petroleum Products and Lubricants in an attempt to supply this need. This classification was first presented in June, 1934, and has been revised periodically.

It is not the intention of the committee that this classification should be used as a purchase specification; but rather that fuels purchased be correlated according to the proposed classification in order to determine its usefulness. A series of Diesel-fuel-oil specifications should evolve as a result of this program. Criticism and comment should be forwarded to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 50 West 50th Street, New York, N. Y.

TABLE I.—DIESEL-FUEL-OIL CLASSIFICATION.

Grade of Diesel Fuel Oil	Flash Point, deg. Fahr.	Water and Sediment, per cent by volume	Saybolt Universal Viscosity (at 100 F.), sec.		Carbon Residue, per cent by weight	Ash, per cent by weight	Pour Point, deg. Fahr.	Sulfur, per cent by weight	Alkali and Mineral Acid	Ignition Quality
	Min.[a]	Max.	Min.[b]	Max.	Max.	Max.	Max.[c]			
No. 1-D	115 or legal	0.05	33	50	0.2	0.02	35	[d]	none	[e]
No. 3-D	150	0.1	33	70	0.5	0.02	35	[d]	none	[e]
No. 4-D	150	0.6	..	250	3.0	0.04	35	[d]	none	[e]

Oils more viscous than No. 4-D are available and may be purchased by special negotiations between the purchaser and the seller.

[a] Minimum flash point, as stated or as required by local fire regulations, fire underwriters, or state laws.

[b] For viscosities below 40 sec. Saybolt, it is suggested that kinematic viscosity be determined by the Tentative Methods of Test for Kinematic Viscosity (A.S.T.M. Designation: D 445)[1] and the values converted to Saybolt seconds by use of the tables in the Tentative Method for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity (A.S.T.M. Designation: D 446)[2] of the American Society for Testing Materials.

[c] Lower pour points may be specified whenever required by local temperature conditions to facilitate storage and use.

[d] So far as known, sulfur content need not be considered as regards combustion characteristics. However, when sulfur content is of consequence—as, for instance, in fuel for engines in intermittent service—the following limits are suggested:

Grade No. 1-D	1.5 per cent max.
Grade No. 3-D	1.5 per cent max.
Grade No. 4-D	2.0 per cent max.

[e] See Table II.

TABLE II.—IGNITION QUALITY.

	Grade No. 1-D	Grade No. 3-D	Grade No. 4-D
Cetane number, min	45	35	30
Diesel index number,[a] min	45	32	25

[a] In many cases the Diesel Index may prove more convenient than cetane number and equally satisfactory. It is reliable for hydrocarbon fuels which have 50 per cent boiling points between 490 and 575 F. It cannot apply in the case of fuel containing an ignition promotor ("doped" fuel).

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[1] See p. 900.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 911 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 845.

METHODS OF TESTING

The properties listed in this classification are determined in accordance with the following methods of testing:

(*a*) *Flash Point.*—In absence of legal or local requirements, the minimum flash point shall be determined in accordance with the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93) of the American Society for Testing Materials.[1]

(*b*) *Water and Sediment.* — Standard Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge (A.S.T.M. Designation: D 96) of the American Society for Testing Materials.[2]

(*c*) *Viscosity.*—Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88) of the American Society for Testing Materials.[3]

(*d*) *Carbon Residue.*—Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (A.S.T.M. Designation: D 189) of the American Society for Testing Materials.[4]

(*e*) *Ash.*—Tentative Method of Test for Ash Content of Petroleum Oils (A.S.T.M. Designation: D 482) of the American Society for Testing Materials.[5]

(*f*) *Pour Point.*—Standard Method of Test for Cloud and Pour Points (A.S.T.M. Designation: D 97) of the American Society for Testing Materials.[6]

(*g*) *Sulfur.*—Standard Method of Test for Sulfur in Petroleum Oils by Bomb Method (A.S.T.M. Designation: D 129) of the American Society for Testing Materials.[7]

(*h*) *Alkali and Mineral Acid.*—Tentative Method of Test for Neutralization Number of Petroleum Products and Lubricants (A.S.T.M. Designation: D 188) of the American Society for Testing Materials.[8]

(*i*) *Ignition Quality*:

CETANE NUMBER.—Proposed Method of Test for Ignition Quality of Diesel Fuels.[9]

DIESEL INDEX NUMBER.—Diesel Index number is calculated from aniline point and A.P.I. gravity by the following formula:

$$\text{Diesel Index Number} = \frac{G \times A}{100}$$

where:

G = the A.P.I. gravity at 60 F., and
A = the aniline point in deg. Fahr.

Aniline Point is the lowest temperature at which equal parts by volume of freshly distilled aniline and the test sample of oil are completely miscible. It is determined by heating such a mixture in a jacketed test tube to a clear solution and noting the temperature at which turbidity appears as the mixture is cooled.

For A.P.I. Gravity see the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287) of the American Society for Testing Materials.[10]

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 897.

[2] *Ibid.*, p. 1001.

[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 148.

[4] 1936 Book of A.S.T.M. Standards, Part II, p. 849.

[5] See p. 865.

[6] 1936 Book of A.S.T.M. Standards, Part II, p. 853.

[7] *Ibid.*, p. 974.

[8] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 927 (1927); also 1938 Book of A.S.T.M. Tentative Standards, 802.

[9] See p. 392.

[10] 1937 Supplement to Book of A.S.T.M. Standards, p. 121.

REPORT OF SECTIONAL COMMITTEE
ON
PETROLEUM PRODUCTS AND LUBRICANTS
A.S.A. PROJECT: Z11

Sectional Committee Z11 on Petroleum Products and Lubricants held two meetings during the year: on June 30, 1937, and on March 15, 1938, both in New York City.

Progress has been made in the preparation of the several sections of the Summary of Work in the Field of Petroleum Products. The Sections on "Gasoline," prepared by T. A. Boyd, "Lubricating Oils," by J. C. Geniesse, and "Status of Research on Fuel and Lubricating Oil for Spark Ignition Aircraft Engines," by S. D. Heron are now before the sectional committee for approval for publication. The following sections are in course of preparation: "Petroleum Greases" by M. B. Chittick, "Diesel Fuels" by T. B. Rendel, and "Fuel Oils (Other than Diesel Fuels)" by H. V. Hume. It is expected that they will be available shortly.

The scope of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants, which was identical with the scope of Sectional Committee Z11, has been enlarged, and since it is felt that a parallelism should be retained between the scopes of the two committees, a similar revision is being proposed in the scope of the sectional committee, as follows:

> The scope of the activities of the sectional committee shall include specifications, methods of test, and nomenclature relating to crude petroleum and petroleum products (products derived in whole or in large part from petroleum) other than asphalts, road oils, paint thinners, and electrical insulating materials.

The Study Committee on Boundary Lubrication (J. C. Geniesse, chairman) has received a definition for "oiliness" from the committee of the Society of Automotive Engineers now at work on defining terms used in boundary lubrication. It is felt, however, that certain modifications will be needed before this definition can be used as a basis for the committee's discussions. The Study Committee plans to consider certain basic definitions relating to lubrication, such as, "fluid film lubrication," "boundary lubrication," etc., which would lead up to a definition for oiliness.

While Specifications for Gasoline (D 439 – 37 T) were issued as tentative by the A.S.T.M. last year, these do not cover gasoline for heavy duty service. It is felt that this subject is one of sufficient importance to warrant further study and the matter has accordingly been referred to Technical Committee A on Gasoline of A.S.T.M. Committee D-2, which committee is soliciting the cooperation of the American Transit Association.

In line with its function as a reviewing body, the sectional committee has taken action during the year on five A.S.T.M. methods for reference to the American Standards Association for approval either as American standard or American tentative standard. At its meeting held during this annual meeting, on the recommendation of A.S.T.M. Committee D-2, action was taken to refer five additional methods to the A.S.A., subject to letter ballot of the sectional committee.

Respectfully submitted on behalf of the committee,

T. A. BOYD,
Chairman.

R. E. HESS,
Secretary.

REPORT OF COMMITTEE D-3
ON
GASEOUS FUELS

Committee D-3 on Gaseous Fuels and its various subcommittees held two meetings in the past year: one in Cleveland, Ohio, in September, 1937, and the other in Rochester, N. Y., in March, 1938. In addition, certain of the subcommittees held interim meetings.

No tentative standards are submitted at this time, but progress has been made in laying the groundwork for standard methods of tests, as indicated in the following brief reports of activities of the subcommittees:

Subcommittee I on Collection of Gaseous Samples (S. S. Tomkins, chairman).—The formation of definitions covering terms in common use relating to sampling is nearing completion and a study of fundamentals is in progress. Separate methods of sampling applicable to manufactured, natural, and liquefied petroleum gases are being prepared and will be published individually as soon as available.

Subcommittee II on Measurement of Gaseous Samples (H. S. Bean, chairman).—The subcommittee has continued active experimental work and finds in the use of laboratory wet gas meters for the measurement of gaseous samples that (1) one or more complete revolutions of the meter drum should be used, (2) the temperature of the gas at the time of seal-off should be considered the same as that of the sealing water shown by a thermometer extending well into it, and (3) the presence of an oil fog in a gas may cause an error of a few tenths of one per cent.

The subcommittee also is considering improvements in design and construction of laboratory meters, the development of equipment and procedure for testing such meters with 2- or 5-ft. gas meter provers of a much wider range of rates and with at least the same degree of precision as usually attained with a 0.1-cu. ft. bottle. Study also is being devoted to the time required to saturate the sealing water of a meter with gas and the time it will remain thus saturated.

Subcommittee III on Determination of Calorific Value of Gaseous Fuels (R. B. Harper, chairman).—Analysis of the replies received from 18 organizations in the United States and Canada to a questionnaire on existing practices followed by the industry for heating value determinations indicates that:

1. Investigation of parallel water flow gas calorimetry should precede that of other apparatus and methods, such as those applying to automatic recording calorimetry and gas analysis calorimetry;
2. A tentative method for routine observations with parallel water flow calorimeters, embodying some refinements over present-day methods, should be established. Further improvements resulting from future research can be incorporated from time to time;
3. A referee method should be developed by research, and
4. Other apparatus and methods should be investigated as a later development.

Definitions covering terms relating to calorimetry have been presented to the subcommittee membership and some modifications are now under consideration prior to their acceptance.

Subcommittee IV on Determination of Specific Gravity and Density of Gaseous Fuels (E. F. Schmidt, chairman).—The bibliography on specific gravity and density, compiled by the former chairman, Mr. C. D. Ulmer, is being prepared for publication in the technical press. The formation of standard definitions is nearing completion.

The National Bureau of Standards is cooperating in the preparation of synthetic gases of known composition and specific gravity for testing of specific gravity apparatus, in order to obtain information on the comparative performance of available equipment. The results of this study will provide needed data on the range and accuracy of existing types of apparatus.

Subcommittee V on Determination of Impurities of Gaseous Fuels (E. F. Pohlmann, chairman).—A new tentative method for the determination of total sulfur by the referee method has been prepared and submitted to the committee membership for comment, and another method, said to be accurate to 0.004 grains per hundred cubic feet, is under consideration.

Subcommittee VI on Determination of Water Vapor Content of Gaseous Fuels (A. W. Gauger, chairman).—Definitions covering relative humidity, absolute humidity, and dew point have been prepared and accepted by the subcommittee. Bibliographic and experimental studies were continued under the direction of the chairman at Pennsylvania State College. A report, entitled "Measurement of Moisture Content of Fuel Gases with Conductivity Cells" has been submitted to committee members. The method shows promise, and preliminary sensitivity tests using methane will be made.

Subcommittee VII on Complete Analysis or Chemical Composition of Gaseous Fuels (Martin Shepherd, chairman).—As the result of data secured from a number of representative laboratories engaged in gas analysis during the past year, the following information has been compiled and studied:

1. A list of all types of apparatus for the analysis of fuel gases and the proportion of each in actual use. Such apparatus has been classified with respect to the chemical and physical principles involved, mechanics of volumetric measurement, volumetric accuracy, and arrangement of reaction pipettes confining fluids,
2. General chemical and physical methods used for the analysis of fuel gas, including principally methods of absorption, combustion, and distillation, and the relative use of each, and
3. A list of actual applications made of the observed composition of fuel gases, together with the accuracies required by various laboratories in computing desired values from these analytical data.

A special container for storage and transportation of standard gas samples for comparative analyses was designed. A single sample has been constructed, tested, and approved for use.

Selection has been made of two types of standard gas samples for initial study and the constituents and range of composition of each decided upon. These are, first, carburetted water gas of 500 to 600 B.t.u. per cu. ft. heating value and, second, natural gas of 1100 to 1150 B.t.u. per cu. ft. heating value.

This report has been submitted to letter ballot of the committee, which consists of 29 members; 26 members returned their ballots, of whom 25 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

R. M. CONNER,
Secretary.

REPORT OF COMMITTEE D-4
ON
ROAD AND PAVING MATERIALS

Committee D-4 on Road and Paving Materials held meetings during the year, in New York City on June 29, 1937, and in Rochester, N. Y., on March 11, 1938.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee B-12 on Abrasion of Coarse and Fine Aggregates (Stanton Walker, chairman).—This subcommittee is responsible for the preparation of the Tentative Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131 – 37 T) which is under the joint jurisdiction of Committee C-9 on Concrete and Concrete Aggregates and Committee D-4 on Road and Paving Materials. During the past year in order to meet criticisms received, the subcommittee has developed certain revisions of this method. Section 2 is being changed in order to clarify the description of the machine. It makes clear that the shaft does not pass through the drum; it expresses preference for a rectangular shelf of wear-resistant steel; and it fixes the position of the shelf in relation to the opening in such a manner that no substantial proportion of the charge will come in contact with the removable cover. This latter point was the subject of considerable discussion which led to the conclusion that the operation of the machine might be affected if the impact of the falling charge were received on the cover or if the charge, as a whole, were allowed to slide over the cover.

In Section 3 the weights of the spheres are being changed and a note is being added. This change is recommended to make steel balls more readily available for use. A $1\frac{13}{16}$-in. steel ball bearing weighs 398 g. and a $1\frac{7}{8}$-in. steel ball bearing weighs about 442 g. These sizes are readily available. A $1\frac{27}{32}$-in. steel ball bearing weighing about 419 g. (approximately the average weight required) can be obtained, but it is a special size not obtained as readily as the standard $1\frac{13}{16}$ and $1\frac{7}{8}$-in. sizes. A mixture of five of the $1\frac{7}{8}$-in. and seven of the $1\frac{13}{16}$-in. steel balls can be selected to provide a charge weighing 5000 ± 25 g.; similarly, five $1\frac{7}{8}$-in. and six $1\frac{13}{16}$-in. steel balls will provide a charge meeting the 4583 ± 25 g. limit. A limited amount of data indicates the proposed changes will not affect results of tests sufficiently to require changes in specification limits. Data submitted through the courtesy of the U. S. Bureau of Public Roads show the following:

Abrasive Charge	Size of Ball, in.	Weight of Abrasive Charge, g.	Percentage of Wear		
			Granite	Limestone	Trap
12 cast-iron balls	$1\frac{7}{8}$	5000	28.3	30.7	11.1
12 steel balls	$1\frac{7}{8}$	5260	28.8	31.0	10.6
10 steel balls	$1\frac{7}{8}$	4380	25.5	28.0	10.4
8 large steel balls and 4 small steel balls	$1\frac{7}{8}$ $1\frac{3}{4}$	4925	27.9	30.5	11.2

Figure 1 has been revised to indicate the preference for the rectangular shelf and to show the limits on the position of the shelf with respect to the cover. The method in its completely revised form is appended hereto[1] for information. It was referred to letter ballot of Committee D-4 at its June meeting for presentation to the Society through Committee E-10.[2]

Subcommittee D-4 on Asphalt Planks (R. R. Litehiser, chairman).—For a number of years this subcommittee has been actively engaged in obtaining information which would serve as a reliable basis for recommending specifications for asphalt planks. Proposed specifications have now been prepared and are appended hereto[1] for information. They were referred to letter ballot of Committee D-4 at its June meeting for presentation to the Society later in the year through Committee E-10 on Standards.[2]

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

A new Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates has been prepared by a Conference Committee created from representatives of Committee D-4 and Committee C-9 on Concrete and Concrete Aggregates for the purpose of drafting a single method of test to replace the following existing standards:

Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 18 – 16),
Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 19 – 16),
Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete (D 7 – 27), and
Test for Sieve Analysis of Aggregates for Concrete (C 41 – 36).

Committee D-4 joins with Committee C-9 in recommending that the new method, appended hereto,[3] be accepted for publication as tentative to replace the above four standard methods which are accordingly recommended to be withdrawn.

During the past two years the committee has carefully reviewed the existing tentative and standard specifications covering crushed stone and crushed slag for the purpose of bringing them up to date and effecting such simplification, by combination of two or more into a single specification, as seemed desirable. The committee now recommends that the following new specifications appended hereto[4] be accepted for publication as tentative to replace the existing specifications, which are recommended to be withdrawn as indicated below:

New Tentative Specifications for:

Crushed Stone for Waterbound Base and Surface Courses, to replace Tentative Specifications for Broken Stone for Waterbound Base (D 190 – 29 T), and Standard Specifications for Broken Stone for Waterbound Macadam Surface Course (D 191 – 29),
Crushed Slag for Waterbound Base and Surface Courses, to replace Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (D 65 – 23), and for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 – 23),
Crushed Stone for Bituminous Macadam Base and Surface Courses, to replace Standard Specifications for Broken Stone for Bituminous Macadam (D 192 – 29),
Crushed Slag for Bituminous Macadam Base and Surface Courses, to replace Standard Specifications for Broken Slag for Bituminous Macadam Base (D 195 – 27), and for Broken Slag for Bituminous Macadam Wearing Course (D 159 – 27),
Crushed Stone for Bituminous Concrete Base and Surface Courses, to replace Tentative Specifications for Broken Stone for Bituminous Concrete Base (D 193 – 29 T), and Standard Specifications for Broken Stone for Bituminous Concrete Surface (D 194 – 29), and

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[1] See pp. 803 and 916.
[2] See Editorial Note, p. 407.
[3] See p. 808.
[4] See pp. 939, 936, 933, 930, 927, 924.

Crushed Slag for Bituminous Concrete Base and Surface Courses, to replace Standard Specifications for Broken Slag for Bituminous Concrete Base (D 196 – 27), for Broken Slag for Bituminous Concrete (Fine-Graded Aggregate Type) (D 161 – 27), and for Broken Slag for Bituminous Concrete (Coarse-Graded Aggregate Type) (D 160 – 27).

During the past year a critical review also has been made of the existing tentative specifications for tars. These specifications have been regrouped and combined, and provision has been made for additional grades as defined by consistency limits. As a result of this work, new Specifications for Tar have been prepared which the committee recommends be accepted for publication as tentative, as appended hereto.[1] These new specifications are to replace the following tentative specifications which are accordingly recommended to be withdrawn:

Tentative Specifications for:

Low-Carbon Tar for Surface Treatment, Cold Application (D 105 – 36 T),
High-Carbon Tar for Surface Treatment, Cold Application (D 104 – 36 T),
Low-Carbon Tar for Surface Treatment, Hot Application (D 109 – 36 T),
High-Carbon Tar for Surface Treatment, Hot Application (D 108 – 36 T),
Low-Carbon Tar Cement (D 111 – 36 T),
High-Carbon Tar Cement (D 110 – 36 T),
Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 107 – 28 T), and
High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 106 – 28 T).

Tentative Revision of Standard:

To meet certain criticisms of the Standard Method of Test for Ductility of Bituminous Materials (D 113 – 35)[2] and to bring this method in line with present practice Committee D-4 recommends that the following proposed revision be accepted for publication as tentative:

Section 5.—Change the second sentence to read as follows by the addition of the italicized words:

> It shall then be strained through a No. 50 sieve *conforming to the requirements prescribed in the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials* and, after a thorough stirring, poured into the mold.

Change the last sentence to read as follows by the addition of the italicized words:

> It shall be left to cool to room temperature *for a period of from 30 to 40 min.*, and then placed in the water bath maintained at the specified temperature of test for 30 min., after which the excess bitumen shall be cut off by means of a hot straight-edged putty knife or spatula so that the mold shall be just level full.

Change the Note following this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> NOTE.—When paving asphalt cements are being tested, the oil bath shall be maintained at a temperature of from [125 to 150 C. (257 to 302 F.)] *150 to 160 C. (302 to 320 F.)*.

Section 6.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> 6. The brass plate and mold, with briquet, shall then be placed in the water bath and kept at the specified temperature for [at least 1½ hours] *a period of from 85 to 95 min.*, when the briquet shall be removed from the plate, the side pieces detached, and the briquet tested immediately.

Section 7.—In the first and last sentences of this section change the words "ductility machine" to read "testing machine."

Adoption as Standard of Tentative Revision of Standard:

Subsequent to the 1937 annual meeting, Committee D-4 presented to the Society through Committee E-10 on Standards a tentative revision of the Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 24).[3] The proposed revision was accepted[1] for publication as tentative on October 11, 1937, and appears in the 1937 *Proceedings*.[2]

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[1] See p. 921.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1058.

[3] 1936 Book of A.S.T.M. Standards, Part II, p. 1103.

No criticism of this tentative revision has been received and Committee D-4 therefore recommends that it be referred to letter ballot of the Society for adoption and incorporation in the present Standard Method D 61, this recommendation requiring a nine-tenths vote at the annual meeting for immediate adoption.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Method of Test for Sieve Analysis of Fine and Coarse Aggregates, to replace Methods D 18 - 16, D 19 - 16, D 7 - 27, and C 41 - 36	62	0	11
Specifications for Crushed Stone for Waterbound Base and Surface Courses, to replace Specifications D 190 - 29 T and D 191 - 29	58	0	15
Specifications for Crushed Slag for Waterbound Base and Surface Courses, to replace Specifications D 65 - 23 and D 66 - 23	52	0	21
Specifications for Crushed Stone for Bituminous Macadam Base and Surface Courses (D 192 - 38 T), to replace Specifications D 192 - 29	58	0	15
Specifications for Crushed Slag for Bituminous Macadam Base and Surface Courses, to replace Specifications D 195 - 27 and D 159 - 27	53	0	20
Specifications for Crushed Stone for Bituminous Concrete Base and Surface Courses, to replace Specifications D 193 - 29 T and D 194 - 29	58	0	15
Specifications for Crushed Slag for Bituminous Concrete Base and Surface Courses, to replace Specifications D 196 - 27, D 161 - 27, and D 160 - 27	52	0	21
Specifications for Tar:[a]			
Low-Consistency Tar	36	2	35
Medium-Consistency Tar	36	2	35
Heavy-Consistency Tar	36	2	35
Extra-Heavy-Consistency Tar	38	1	34
Cut-Back Tar	37	1	35
II. TENTATIVE REVISION OF STANDARD			
Method of Test for Ductility of Bituminous Materials (D 113 - 35)	56	1	16
III. ADOPTION AS STANDARD OF TENTATIVE REVISION OF STANDARD			
Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 - 24), immediate adoption	46	0	27

[a] The specifications for tar are to replace Specifications D 105 - 36 T, D 104 - 36 T, D 109 - 36 T, D 108 - 36 T, D 111 - 36 T, D 110 - 36 T, D 107 - 28 T, and D 106 - 28 T.

Editorial Change in Standard:

At its June, 1938, meeting, Committee D-4 adopted the following editorial revision in the Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (D 75 - 22):

Section 8 (a).—Change this section from its present form: namely,

> 8. (*a*) The sample of crushed stone for mechanical analysis shall weigh at least 50 times the weight of the largest piece therein.

to read as follows:

> 8. (*a*) Samples of crushed stone for mechanical analysis shall conform to the following requirements as to weight:

NOMINAL MAXIMUM SIZE OF PARTICLE, IN.	MINIMUM WEIGHT OF SAMPLE, G.
$\frac{3}{8}$	1 000
$\frac{1}{2}$	2 500
$\frac{3}{4}$	5 000
1	10 000
$1\frac{1}{2}$	15 000
2	20 000
$2\frac{1}{2}$	25 000
3	30 000
$3\frac{1}{2}$	35 000

Since this revision is merely an editorial change to bring the existing standard method of sampling into conformity with recently adopted methods of test, Committee D-4 requests that it be so considered by the Society and immediately embodied in the present standard.

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[1] In submitting the tentative revision to Committee E-10 on Standards, Committee D-4 reported results of the letter ballot as follows: Of a total membership of 104, 61 members returned their ballots, of whom 53 voted affirmatively, 0 negatively, and 8 members marked their ballots "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1321 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1579.

At its June, 1938, meeting Committee D-4 also referred to letter ballot for recommendation to the Society through Committee E-10 on Standards the proposed tentative coefficients of expansion for tars as published in the 1938 Report of Committee D-8 on Bituminous Roofing and Waterproofing Materials.[1,2]

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 106 members; 73 members returned their ballots, the results being given in Table I.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, E. F. Kelley.
First Vice-Chairman, J. E. Myers.
Second Vice-Chairman, A. T. Goldbeck.
Third Vice-Chairman, E. O. Rhodes.
Secretary, Prévost Hubbard.

This report has been submitted to letter ballot of the committee which consists of 106 members; 73 members returned their ballots, of whom 69 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

F. C. LANG,
Chairman.

PRÉVOST HUBBARD,
Secretary.

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[1] See p. 417.

[2] It was not found possible to complete the table of coefficients in time for its presentation to the Society in 1938.

EDITORIAL NOTE

Subsequent to the annual meeting, Committee D-4 on Road and Paving Materials presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Specifications for Asphalt Plank, and
Proposed Revision of Tentative Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine (C 131 – 37 T), recommended jointly with Committee C-9 on Concrete and Concrete Aggregates.

These recommendations were accepted by Committee E-10 and appear on pp. 916 and 803, respectively.

REPORT OF COMMITTEE D-5 ON COAL AND COKE

Committee D-5 on Coal and Coke held three meetings during the past year; in New York City on June 28, 1937, in Pittsburgh, Pa., on October 26, 1937, and in Rochester, N. Y., on March 7, 1938.

A new subcommittee, under the chairmanship of Mr. R. A. Sherman and designated Subcommittee XVI on Ignitability of Coal and Coke, has been formed to investigate methods for determination of ignition characteristics of solid fuels with a view of developing a standard method of test. Ignition characteristics of solid fuels are considered important in connection with various methods of burning.

Another new subcommittee, under the chairmanship of Mr. G. B. Gould and designated Subcommittee XVII on Significance of Tests of Coal and Coke, has been formed to prepare a report on the significance of the standard tests of coal and coke, also to prepare a further report covering the same subject but in briefer form for publication in a compilation with suitable types of purchase specifications for coal, with particular regard to purchases by small consumers.

Subcommittee VI on Agglutinating Value has been discontinued and work on the agglutinating value test is being conducted by Subcommittee I on Methods of Testing. Subcommittee XII on Sampling Coal at Coal Cleaning Plants was combined with Subcommittee XIII on Mechanical Sampling and Reduction of Samples and the combined subcommittee, under the chairmanship of Mr. J. B. Morrow, designated as Subcommittee XIII on Coal Sampling.

The committee wishes to record its appreciation of the work of a special committee which was responsible for securing the papers comprising the Symposium on Significance of Tests of Coal held at the 1937 annual meeting of the Society. This committee consisted of A. W. Gauger, chairman, G. B. Gould, J. B. Morrow, and A. H. Emery. The papers are published in the *Proceedings*[2] and have also been issued as a separate reprint.

It is with regret that the committee records the death of Mr. J. A. Capp, who for many years served as a member of the committee. The membership of the committee now totals 44, of whom 15 are classified as consumer, 10 as producer, and 19 as general interest members.

Recommendations Affecting Standards

New Tentative Standard:

The committee recommends that the new Tentative Method of Sampling Coals Classed According to Ash Content be accepted for publication as tentative, as appended hereto.[1] This method is applicable to ordinary commercial sampling of coal and is designed to have an accuracy such that in 95 cases out of 100, the ash content of the sample will be within plus or minus 10 per cent of the true ash content of the coal sampled. A modification of the method is given also for conditions requiring greater accuracy.

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[1] See p. 912.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part II, pp. 341 to 466 (1937).

Tentative Revision of Standard:

A tentative revision of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 37) is recommended by the committee for publication. This proposed revision provides for a change in the form of the method for determination of fusibility of ash to give the essential furnace requirements and procedure together with mention of specific furnaces which the committee has investigated and approved.

Adoption of Tentative Standard as Standard:

The committee recommends that the Tentative Method of Test for Screen Analysis of Coal (D 410 – 35 T)[1] be revised as follows and referred to letter ballot of the Society for adoption as standard:

Section 2.—Omit Paragraph (*a*) which reads as follows, relettering the subsequent paragraphs accordingly:

> (*a*) *Gage Rings or Plates.*—Gage rings or gage plates with 8, 6, and 5-in. diameter openings. The actual diameters of openings shall not vary from the nominal diameters more than ±3 per cent.

Change Paragraph (*b*) to read as follows by the addition of the italicized figures, relettering this paragraph as Paragraph (*a*):

> (*a*) Round-Hole Screens.—Round-hole screens with *8*, *6*, *5*, 4, 3, 2½, 2, 1½, 1¼, 1, ¾, ½, and ⅜-in. diameter openings, conforming to the Standard Specifications for Round-Hole Screens for Testing Purposes (A.S.T.M. Designation: E 17) of the American Society for Testing Materials.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 44 members; 38 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Method of Sampling Coals Classed According to Ash Content	34	2	2
II. TENTATIVE REVISION OF STANDARD			
Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 37)	36	0	2
III. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method of Test for Screen Analysis of Coal (D 410 – 35 T), as revised	33	2	3

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Methods of Testing (W. A. Selvig, chairman).—The subcommittee held two meetings during the past year: in Pittsburgh, Pa., on October 26, 1937, and in Rochester, N. Y., on March 7, 1938. It completed its assignment of revising the method of determination of fusibility of ash as given in the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 37). This revision, appended hereto,[2] permits the use of either gas or electric furnaces which meet specified requirements as to temperature regulation and atmosphere control. It mentions names of commercial furnaces that on trial have been found to give satisfactory results. This form of method is adapted to the inclusion of commercial furnaces which may be developed in the future for this determination provided they are found to be satisfactory upon investigation by Committee D-5. The present standard method as written is confined to detailed description of two commercial gas-fired furnaces and, consequently, is not well adapted to the inclusion of other furnaces that may be equally satisfactory.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 863 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 628.

[2] See p. 1339.

A special section of the subcommittee, under the chairmanship of Mr. C. C. Russell, will investigate methods for determination of cubic foot weights of crushed bituminous coal as charged into coke ovens with a view to revising the Standard Method of Test for Cubic Foot Weight of Crushed Bituminous Coal (D 291 - 29). Experimental data available show that cubic foot weights as determined by the standard method may be appreciably lower than the weight per cubic foot of coal in the coke oven. The higher values for coal in the oven are due probably to the packing effect caused by dropping the coal from a considerable height, and to the influence of heat as the coal is charged into hot ovens.

Subcommittee II on Nomenclature and Definitions (H. C. Porter, chairman).—Upon recommendation of Subcommittee II, the Tentative Definition of the Term Coke (D 121 - 30 T) is being continued as tentative, pending further consideration by Committee E-8 on Nomenclature and Definitions.

The Tentative Definitions of the Terms Gross Calorific Value and Net Calorific Value of Fuels (D 407 - 35 T) are being continued as tentative to afford further opportunity for criticism.

Subcommittee VIII on Foundry Coke Specifications (J. T. MacKenzie, chairman).—A meeting of this subcommittee was held in Rochester, N. Y., on March 7, 1938. The subcommittee has under consideration specifications for foundry coke based on tolerances for the variation of analyses which may be permitted from analytical values stated in any given purchase specifications. Consideration is being given also to sampling coke for size testing as the question of size is one of the most important properties of coke for foundry use.

Subcommittee XIII on Coal Sampling (J. B. Morrow, chairman).—This subcommittee held a meeting in Pittsburgh, Pa., on October 26, 1937. It has been very active during the past year in formulating the new Tentative Method of Sampling Coals Classed According to Ash Content, appended hereto.[1] A great deal of experimental data on coal sampling has been collected and analyzed by the subcommittee during the last six or seven years. Attention has been given the extensive work on coal sampling of the British Standards Institution and of the Fuel Research Institute of South Africa. The statistical method developed in the works of the British Standards Institution, of calculating number and size of increments required in collecting gross samples to give a prescribed accuracy, has been followed in formulating the proposed tentative method.

In the proposed method, coals are divided for sampling into four groups, depending on ash content, and each group is subdivided according to size of coal. The minimum size of increments as given is based on the quantity of coal necessary to represent the true size consist of the coal sampled.

Two schemes of coal sampling are given, one is for ordinary commercial sampling and is designed to give results so that 95 per cent of the test results will fall within plus or minus 10 per cent of the true ash content of the coal sampled. The other scheme is intended for purposes requiring greater accuracy, such as sampling for classification of coal by grade or rank, or sampling for performance test work. In this latter scheme the minimum number of increments specified is five times that specified for commercial sampling purposes.

Subcommittee XV on Plasticity and Swelling of Coal (C. C. Russell, chairman).—This subcommittee held two meetings during the year: in New York City on June 28, 1937, and in Johnstown, Pa., on February 18, 1938. The work of the subcommittee at present has been confined mainly to studies of methods for testing expanding properties of coals during coke manufacture. A special section of the subcommittee is being formed to investigate plastic properties of coals as affecting their combustion characteristics. In connection with testing expanding properties of coal during carbonization in coke ovens, arrangements are being made to distribute samples of coal of various ranks to different laboratories for making expansion tests by various methods. Such preliminary cooperative testing is believed necessary in the selection or development of a standard test procedure.

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[1] See p. 912.

Subcommittee XVI on Ignitability of Coal and Coke (R. A. Sherman, chairman).—This subcommittee held an organization meeting in Pittsburgh, Pa., on October 26, 1937. Abstracts have been prepared of a number of published papers pertaining to ignitability for circulation among members of the subcommittee.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 44 members; 38 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

W. A. SELVIG,
Secretary.

REPORT OF SECTIONAL COMMITTEE
ON
CLASSIFICATION OF COALS

A.S.A. PROJECT: M20

The Sectional Committee on Classification of Coals, functioning under the procedure of the American Standards Association, held one meeting during the past year, in New York City, on February 16, 1938.

L. W. Hildreth was appointed as an alternate representative of the Anthracite Institute, *vice* R. H. Buchanan, resigned. E. G. Bailey was appointed as the representative of the American Society of Mechanical Engineers.

It is with regret that the committee records the death of Malcolm Macfarlane, representative of the International Railway Fuel Association on the sectional committee, and the death of R. Thiessen who took an active part in the work of the Technical Committee on Coal Classification.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

The committee recommends that the Tentative Definitions of Varieties of Coals be accepted for publication as tentative, as appended hereto.[1] These definitions apply only to commercial varieties of bituminous and subbituminous coals.

Revision of Standards:

The committee recommends for immediate adoption, the following revision of the Standard Specifications for Classification of Coals by Rank (D 388 - 37)[2] and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that this modification may be referred to letter ballot of the Society:

Section 10 (*b*).—Change to read as follows by the addition of the italicized words and figures:

(*b*) In case of controversy, samples containing more than 1.0 per cent of carbon dioxide occurring as carbonates shall be either (1) crushed to pass through an 840-micron (No. 20) sieve and floated on a heavy liquid of such specific gravity as to reduce the carbon dioxide occurring as carbonate to 1.0 per cent or less on a dry basis, provided, however, that the recovery of float coal shall not be less than 75 per cent; or (2) shall be analyzed for mineral matter according to the Parr method[a] for coals with high calcium carbonate content, *modified by heating the sulfated ash at 750 C. to constant weight to insure expulsion of excess sulfur trioxide.*[b] In case of litigation, method (1) shall be used.

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[a] S. W. Parr, "Chemical Study of Illinois Coal," Illinois Coal Mining Investigations, State Geological Survey, Urbana, Ill., *Bulletin No. 3*, p. 35 (1916).

[b] *O. W. Rees, "Determining Ash in High Carbonate Coals. Study of the Modified Method," Industrial and Engineering Chemistry, Analytical Edition, Vol. 9, pp. 307–309 (1937).*

These specifications have been approved as American standard by the American Standards Association (A.S.A. No. M20.1–1937) and are recommended for reapproval as American standard in their revised form upon their adoption as an A.S.T.M. standard.

Adoption of Tentative Standard as Standard:

The committee recommends that the Tentative Method for Designating the

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[1] See p. 915.

[2] 1937 Supplement to Book of A.S.T.M. Standards, p. 144.

Size of Coal from Its Screen Analysis (D 431 - 36 T)[1] be approved for reference to letter ballot of the Society for adoption as standard. The committee further recommends that this method be submitted to the American Standards Association for approval as American standard upon its adoption by the A.S.T.M.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 28 members; 24 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Definitions of Varieties of Bituminous and Subbituminous Coals	23	0	1
II. REVISION OF STANDARD			
Specifications for Classification of Coals by Rank (D 388 - 37), immediate adoption	22	0	2
III. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method for Designating the Size of Coal from Its Screen Analysis (D 431 - 36 T)	20	0	4

ACTIVITIES OF TECHNICAL COMMITTEES

Technical Committee on Coal Classification (H. J. Rose, chairman).—During the past year, this technical committee held two meetings: one in Pittsburgh, Pa., on October 26, 1937, and the other in New York City, on February 16, 1938.

A revision, as given earlier in this report, is recommended for immediate adoption in the Standard Specifications for Classification of Coals by Rank (D 388 - 37). This revision introduces no change in the specifications except the modification of an analytical procedure necessary to obtain accurate results. The Tentative Method for Designating the Size of Coal from Its Screen Analysis (D 431 - 36 T) is recommended for adoption as standard.

Technical Committee on Nomenclature (E. A. Holbrook, chairman).—This technical committee held two meetings during the past year, in Pittsburgh, Pa., on October 27, 1937, and in New York City, on February 16, 1938. The committee has prepared definitions of terms relating to commercially recognized varieties of bituminous and subbituminous coal other than those of rank and grade, and these definitions are submitted for publication as tentative, as appended hereto.[2] The varieties which are defined are common banded coal, splint coal, cannel coal, and boghead coal.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 28 members; 24 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

J. D. BATTLE,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 819 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 632.

[2] See p. 915.

REPORT OF COMMITTEE D-7
ON
TIMBER

Committee D-7 on Timber presents herewith an informational report of its activities during the past year. The committee has held one meeting, in Chicago, Ill., on March 15, 1938.

During the year Committee D-7 has lost two of its most valued members by death, Messrs. S. R. Church and Ernest Bateman. Mr. Church had been a member of the Society since 1907 and also a member of Committee D-7 since that time. Mr. Bateman joined the Society in 1914 and had served since that time as a member of Committee D-7. Both were keen students, active in their chosen field dealing with timber preservation. They had much to do with the development of the standards relating to timber and timber preservatives promulgated by the Society during the past twenty-five years. The committee wishes to record its sense of loss, and to extend to the respective families its sincere sympathy.

RECOMMENDATIONS AFFECTING STANDARDS

Revision of Tentative Standard:

The committee is submitting a revision of the Tentative Method of Test for Tar Acids in Creosote and Creosote – Coal Tar Solutions (D 453 – 37 T) with respect to the description of the tar acid funnels, as proposed by Subcommittee VI, and recommends that the method as revised be continued as tentative.

This recommendation has been submitted to letter ballot of the committee, which consists of 24 members; 22 members returned their ballots, of whom 19 have voted affirmatively, 0 negatively, and 3 members marked their ballots "not voting."

Tentative Specifications and Revision Continued as Tentative:

In view of the fact that the Tentative Specifications for Zinc Chloride (D 432 - 36 T) are still being considered by other technical bodies, the committee recommends that these specifications be continued as tentative for another year.

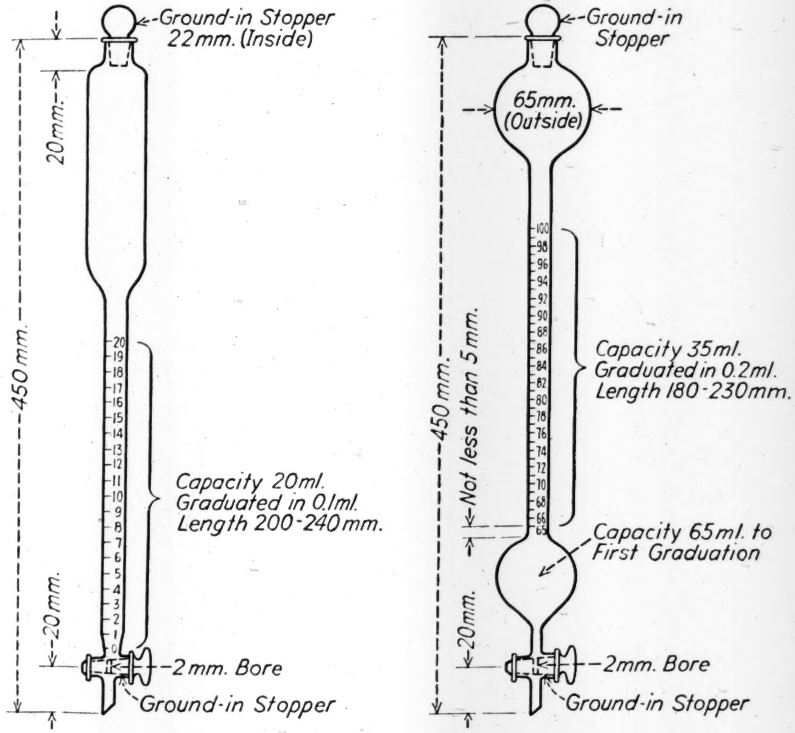
The definition of the term "water-gas tar," which is intended when adopted to be added to the Standard Definitions of Terms Relating to Timber Preservatives (D 324 – 33), has been tentative since 1933. The definition is under consideration by a Subcommittee on Definitions Relating to Bituminous Materials, of Committee E-8 on Nomenclature and Definitions, composed of representatives of the several standing committees of the Society interested in nomenclature relating to this field. Since the subcommittee plans to present a revised definition during the year, it is recommended that the present definition be continued as tentative.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Specifications for Timber (C. E. Paul, chairman).—Subcommittee I has completed the study and revision of standards for structural timber, no further suggestions having been received with reference to the Standard Specifications for Timber Piles (D 25 - 37). The subcommittee has been active during the year in endeavoring to secure approval of the Specifications for Timber Piles on the part of other organizations with a view to having these specifications submitted to the American Standards Association for approval as American standard.

This committee has also considered studying the question of an interpretation of knot measurement descriptions, particularly when applied to oak piles. This is a subject concerning which further action may be expected next year.

Subcommittee VI on Timber Preservatives (C. S. Reeve, chairman).—This subcommittee has considered the Tentative Method of Test for Tar Acids in Creosote and Creosote - Coal Tar Solutions (D 453 - 37 T),[1] presented for publication last year, and has one recommendation to make. Committee No. 4 on Preservatives of the American Wood-Preservers' Association has revised the description of the separatory funnels required in this test for tar acids, and this revision was approved by Technical Committee XII on Laboratory Glassware of the Society's Committee E-1 on Methods of Testing at a meeting held in Rochester, N. Y., March, 1938. The change in the description is generally regarded as a decided improvement. It involves a slight revision of the text and a change in certain details of the glass funnels to bring them into accord with current production of the apparatus. The subcommittee accordingly recommends that Method D 453 - 37 T be


Ground-in Stopper 22mm. (Inside)
20mm.
450mm.
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Capacity 20ml. Graduated in 0.1ml. Length 200-240mm.
20mm.
2mm. Bore
Ground-in Stopper
Ground-in Stopper
65mm. (Outside)
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
65
Capacity 35ml. Graduated in 0.2ml. Length 180-230mm.
450mm.
Not less than 5mm.
Capacity 65ml. to First Graduation
20mm.
2mm. Bore
Ground-in Stopper

Type I, 200-ml. Capacity. Type II, 260-ml. Capacity.

FIG. 1.—Glass Separatory Funnels for Tar Acid Test of Creosote.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 832 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 651.

revised as follows and continued as tentative:

Section 2.—Change to read as follows by the addition of the italicized words and figures and the omission of the figure in brackets:

2. (*a*) Type I, Separatory Funnel.—The Type I glass separatory funnel shall conform to the requirements shown in Fig. 1 (*a*). It shall have a total capacity of [175] *approximately 200* ml. with the lower 20 ml. graduated accurately in 0.1 ml. *The graduation marks shall be numbered for each milliliter.*

(*b*) Type II, Separatory Funnel.—The Type II glass separatory funnel *shall have a total capacity of approximately 260 ml. and* shall conform to the requirements shown in Fig. 1 (*b*). The capacity of the lower bulb from the stopcock to the first graduation mark shall be 65 ml. and above this mark the stem shall be graduated accurately for 100 ml. in 0.2 ml. *The graduation marks shall be numbered for each milliliter.*

Fig. 1.—Substitute for the illustration of the glass separatory funnels, identified as Fig. 1, the drawing shown in the accompanying Fig. 1.

Subcommittee X on Nomenclature and Definitions (C. J. Hogue, chairman).—This subcommittee reports progress in studying a possible revision of the nomenclature relating to timber.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee, which consists of 24 members; 22 members returned their ballots, all of whom have voted affirmatively.

Respectively submitted on behalf of the committee,

HERMANN VON SCHRENK,
Chairman.

J. A. NEWLIN,
Secretary.

REPORT OF COMMITTEE D-8
ON
BITUMINOUS WATERPROOFING AND ROOFING MATERIALS

Committee D-8 on Bituminous Waterproofing and Roofing Materials has held two meetings during the past year, in New York City on June 28, 1937, and in Rochester, N. Y., on March 10, 1938.

Subsequent to the 1937 annual meeting, Committee D-8 presented to the Society through Committee E-10 on Standards a proposed Tentative Method of Testing Films Deposited from Bituminous Emulsions (D 466 – 37 T). This proposed method was accepted[1] for publication as tentative on August 26, 1937, and appears in the 1937 *Proceedings*.[2]

ACTIVITIES OF SUBCOMMITTEES

Subcommittee VI on Methods of Fiber Analysis (C. S. Reeve, chairman).—The extension of the present Standard Method of Analysis of Roofing Felt for Fiber Composition (D 272 – 34) for the determination of rayon fibers in roofing felt has been investigated and has been found to offer possibilities, in the hands of a skilled operator, for differentiating either viscose, acetate, or cuprammonium products from the usual components of felt. Felts containing mixtures of these fibers are being prepared for cooperative tests by members of the subcommittee in order to determine the value of the test method when carried out by different operators.

Subcommittee X on Standard Coefficient of Expansion for Bituminous Products (J. S. Miller, chairman).—This subcommittee finds, as a result of an investigation of a large number of samples of both crude tars and finished products made from water-gas tar and coal tar, that there is a distinct linear relation between the specific gravity and coefficient of expansion. The curves representing the two classes of compounds tend to converge as the lower gravities are approached. As a result of this survey and following the practice of the work on petroleum products, the subcommittee recommends coefficients for four types of materials, as follows:

TYPE OF MATERIAL	COEFFICIENT OF EXPANSION AT 60 F., PER DEG. FAHR.
Creosote Oils	0.00040
Tar primers	0.00035
Tar cements	0.00030
Tar pitches	0.00026

These figures represent current practice in the industry and have been adopted by a number of state highway commissions.

It will be noted that in the Standard Abridged Volume Correction Table for Petroleum Oils (D 206 – 36),[3] tables have been calculated for Group 1 for which the coefficient is 0.00040 and for Group 0 the coefficient for which is 0.00035; these have been approved by Committee D-8 for asphaltic products. The recommendation of this subcommittee after approval by the main committee will necessitate the formation of tables for the two new groups, namely, Group 00 using the coefficient of 0.00030 and Group 000 using the coefficient of

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[1] In submitting this tentative method to Committee E-10 on Standards, Committee D-8 reported results of the letter ballot vote as follows: Of a total voting membership of 60, 39 members returned their ballots, of whom 36 voted affirmatively, 0 negatively and 2 members marked their ballots "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats. Vol. 37, Part I, p. 955; also 1937 Book of A.S.T.M. Tentative Standards, p. 948.

[3] 1936 Book of A.S.T.M. Standards, Part II, p. 988.

0.00026. When this is accomplished, all grades of bituminous materials may be covered in one set of standard volume correction tables.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

Tentative Specifications for Asphalt Mastic for Use in Waterproofing (*Asphalt Cement, Mineral Filler, Mineral Aggregates*).—The present Standard Specifications for Asphalt Mastic for Use in Waterproofing (D 169 – 25) require the use of mastic cake in preparing the grade of asphalt mastic covered by the specifications. There is a growing tendency to produce mastics by mixing all of the mineral aggregate constituents, mineral filler, and the asphalt cement on the site of the work. The new specifications appended hereto[1] cover this latter type of mastic and are recommended for publication as tentative.

Revisions of Tentative Standards:

Tentative Specifications for Coal-Tar Pitch for Roofing, Damp-proofing and Waterproofing (*D 450 – 37 T*).—The committee recommends that these specifications be revised as follows and continued as tentative:

Section 6.—Add as Paragraph (*j*) a requirement for flash point to read as follows:

(*j*) Flash point (Cleveland open cup), min..... 248 F. (120 C.)

Tentative Methods of Test for Sieve Analysis of Granular Mineral Surfacing for Asphalt Roofing and Shingles (*D 451 – 37 T*), and *of Non-Granular Mineral Surfacing for Asphalt Roofing and Shingles* (*D 452 – 37 T*).—In both of these methods it is recommended that in the interest of accuracy the following editorial changes be made and the methods continued as tentative:

Section 2 (*b*).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> (*b*) *The* [sieves shall be] wire cloth *for these sieves shall be* [square-] woven (*not twilled*) from brass, bronze, or other suitable wire *and shall be* mounted without distortion in circular frames, about 20 cm. (8 in.) in diameter and about 5 cm. (2 in.) between the top of the frame and the cloth.

Table I.—Omit the note following this table which reads as follows:

> NOTE.—Sieve of the Tyler standard screen scale series, having mesh designations: Nos. 6, 8, 10, 14, 20, 28, 35, 48, 65, and 100, conform respectively, to the requirements in Table I for sieve opening and wire diameter, within the tolerances stated, for the sieves of the U. S. Standard Sieve Series, in the order listed.

Reversion of Standards to Tentative:

Because of contemplated revisions, it is recommended that the following standards[2] be reverted to tentative, this recommendation to become effective in 1939:

Standard Specifications for:

Asphalt Mastic for Use in Waterproofing (D 169 – 25),
Bituminous Grout for Use in Waterproofing Above Ground Level (D 170 – 25),
Bituminous Grout for Use in Waterproofing Below Ground Level (D 171 – 25),
Acid-Resisting Asphalt Mastic (D 223 – 30),
Standard Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (D 147 – 27).

It is recommended further that the following three standards be reverted to tentative and revised as indicated below:

Standard Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (*D 173 – 27*),[3] revised as follows in order to cover present practice:

Section 2.—Change the second sentence to read as follows by the addition of the italicized words:

> This shall be accomplished *either* by passing the fabric through the saturant *or by spraying*

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[1] See p. 973.

[2] 1936 Book of A.S.T.M. Standards, Part II, pp. 1125, 1127, 1129, 1123, and 1143.

[3] *Ibid.*, p. 1134.

with saturant and then calendering it in the presence of heat, whereupon it shall be cooled and wound into rolls.

Section 3.—Change Paragraph (*f*) to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

(*f*) The moisture content based on the net weight shall not be more than [1] *4* per cent.

Change Paragraph (*i*) from its present form: namely,

(*i*) The pliability at 32 F. (O C.) shall not be less than 10.

to read as follows:

(*i*) *Pliability at 32 F. (O C.).*—No cracking of the fabricated bituminized fabric shall take place on bending over a $\frac{1}{16}$-in. mandrel through an arc of 180 deg. in one direction and then through 360 deg. over the same mandrel in the opposite direction.

Change Paragraph (*k*) to read as follows by the addition of the italicized figure and the omission of the word in brackets:

(*k*) The weight of the saturant contained in the fabricated material shall not be less than [twice] *1.6 times* the weight of the moisture-free fabric in the same area.

Standard Specifications for Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (D 226 – 27),[1] revised as follows in order to bring the specifications up to date and to include requirements for 30-lb. material:

New Section.—After the present section on scope add a new Section 2 on Types to read as follows, renumbering the subsequent sections accordingly:

2. *Types.*—Asphalt-saturated felts covered by these specifications are of two types: namely, 15 lb. and 30 lb.

Sections 7 and 8.—Renumber these sections as 8 and 9 and change them from their present form to read as follows:

8. The fabricated bituminized felt shall conform to the following requirements:

	15-LB. TYPE	30-LB. TYPE
(*a*) Width of roll, in.	either 36 or 32 as may be specified ± $\frac{1}{4}$	
(*b*) Area of Roll, min., sq. ft.	432	216
(*c*) Minimum weight of saturated felt per 100 sq. ft. (exclusive of wrapping and packing material), lb.	14	29
(*d*) Loss on heating at 105 C. (221 F.) for 5 hr., max., per cent	4	4
(*e*) Pliability at 77 F. (25 C.). At least 8 strips out of 10 shall not crack when bent 90 deg. at a uniform speed over a rounded corner of	$\frac{1}{2}$ in. rad.	$\frac{3}{4}$ in. rad.
(*f*) Average breaking strength: With fiber grains, min., lb.	30	40
Across fiber grains, min., lb.	15	20
(*g*) Saturant in moisture-free felt by weight, min., per cent	140	150

9. The desaturated moisture-free felt shall conform to the following requirements:

	15-LB. TYPE	30-LB. TYPE
(*a*) Weight per 100 sq. ft., min., lb.	5.2	10.0
(*b*) Ash, max., per cent	10	10

Standard Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing (D 146 – 37),[2] revised as follows in view of the fact that the pliability requirements for saturated felts and fabrics have been revised in Specifications D 173 and D 226, as mentioned above:

Section 13.—Change the test for pliability from its present form to read as follows:

13. (*a*) *Felted Fabrics.*—From the sample selected in accordance with Section 8, ten strips 1 in. in width by 8 in. in length shall be cut, five in the direction of and five across the fiber grain. They shall be immersed in water at 77 F. (25 C.) for 10 to 15 min., then removed and each strip immediately bent 90 deg. over the rounded edge of a block, at a uniform speed in approximately two seconds time. The block shall be 3-in. square by 2 in. in thickness with rounded corners of $\frac{1}{2}$-in. radius for 15-lb. felts and $\frac{3}{4}$-in. radius for 30-lb. felts. In bending, the strips shall be held by hand tightly against the upper 2-in. face of the block, and the projecting end of the strip shall be bent over the rounded corner without exerting any strain other than that required to keep the strip in contact with the block and to avoid kinking. Any surface ruptures exceeding $\frac{1}{8}$ in. in length shall be considered failures.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1137.

[2] 1937 Supplement to Book of A.S.T.M. Standards, p. 223.

(*b*) *Woven Fabrics.*—From the samples selected in accordance with Section 8, five strips 1 in. in width by 6 in. in length shall be cut in the direction of the warp. They shall be immersed in a cooling mixture of ice and water at 0 C. (32 F.) for 10 to 15 min., then removed and each strip immediately bent over a $\frac{1}{16}$-in. mandrel through an arc of 180 deg. at a uniform speed in approximately two seconds and then through 360 deg. over the same mandrel in the opposite direction. The strips shall then be dried thoroughly and examined. If one or more of the test strips crack, ten strips from another portion of the sample shall be cut and the test repeated. If one or more of these strips crack, the material shall be considered as failing to meet the specifications.

Withdrawal of Standard:

Standard Specifications for Burlap Saturated with Bituminous Substances for Use in Waterproofing (*D 174 – 25*).[1]—The use of asphalt and coal-tar saturated burlap for waterproofing has been discontinued because of unsatisfactory behavior in service, and the committee accordingly recommends the withdrawal of these standard specifications.

The recommendations appearing i this report have been submitted to letter ballot of the committee which consist of 58 voting members; 40 member returned their ballots, with the result shown in Table I.

The election of officers for the ensuin term of two years resulted in the selection of the following:

Chairman, J. M. Weiss.
Vice-Chairman, E. H. Berger.
Secretary, Prévost Hubbard.

This report has been submitted t letter ballot of the committee which consists of 58 voting members; 40 members returned their ballots, of whom 38 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf o the committee,

J. M. WEISS,
Chairman.

PRÉVOST HUBBARD,
Secretary.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Specifications for Asphalt Mastic for Use in Waterproofing (Asphalt Cement, Mineral Filler, Mineral Aggregates)	35	0	5
II. REVISIONS OF TENTATIVE STANDARDS			
Specifications for Coal-Tar Pitch for Roofing, Damp-proofing and Waterproofing (D 450 – 37 T)	25	2	13
Method of Test for Sieve Analysis of Granular Mineral Surfacing for Asphalt Roofing and Shingles (D 451 – 37 T), editorial change	32	0	8
Method of Test for Sieve Analysis of Non-Granular Mineral Surfacing for Asphalt Roofing and Shingles (D 452 – 37 T), editorial change	32	0	8
III. REVERSION OF STANDARDS TO TENTATIVE			
Recommendations Effective in 1939:			
Specifications for Asphalt Mastic for Use in Waterproofing (D 169 – 25)	37	0	3
Specifications for Bituminous Grout for Use in Waterproofing Above Ground Level (D 170 – 25)	37	0	3
Specifications for Bituminous Grout for Use in Waterproofing Below Ground Level (D 171 – 25)	37	0	3
Specifications for Acid-Resisting Asphalt Mastic (D 223 – 30)	37	0	3
Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (D 147 – 27)	37	0	3
Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (D 173 – 27), as revised	30	0	10
Specifications for Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (D 226 – 27), as revised	32	1	7
Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing (D 146 – 37), as revised	33	0	7
IV. WITHDRAWAL OF STANDARD			
Specifications for Burlap Saturated with Bituminous Substances for Use in Waterproofing (D 174 – 25)	33	0	7

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1131.

EDITORIAL NOTE

Subsequent to the annual meeting Committee D-8 on Bituminous Waterproofing and Roofing Materials presented to the Society on August 25, 1938, through Committee E-10 on Standards a proposed revision of the Tentative Methods of Testing Films Deposited from Bituminous Emulsions (D 466 - 37 T). This revision was accepted by Committee E-10 and the methods in their revised form appear on p. 992.

REPORT OF COMMITTEE D-9
ON
ELECTRICAL INSULATING MATERIALS

Committee D-9 on Electrical Insulating Materials held two meetings during the year and will hold a third during the annual meeting of the Society in June, 1938, in Atlantic City, N. J. The meetings were held in October, 1937, and February, 1938, with an average attendance of 64 members and 14 visitors. At these meetings considerable progress was made in the work which has been pending before the committee and several projects had reached the stage where definite recommendations were made resulting in additions to or changes in standards. A number of other projects are under way as mentioned later in this report.

Subsequent to the 1937 annual meeting, Committee D-9 presented to the Society through Committee E-10 on Standards proposed Tentative Specifications for Phenolic Laminated Sheet for Radio Applications (D 467 – 37 T), proposed Tentative Method of Testing Pin-Type, Lime Glass Insulators (D 468 - 37 T), and a revision of the Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 37 T). These recommendations were accepted[1] by Committee E-10 on August 26, 1937, and the new and revised tentative standards appear in the 1937 *Proceedings*.[2]

RECOMMENDATIONS AFFECTING STANDARDS

As a result of the year's work, the committee is presenting two new tentative methods of test, revisions of seven tentative standards, tentative revisions of two existing standards, and is recommending the adoption of four tentative standards. The recommendations being presented are included in detail in Appendix I each proposed revision being accompanied by a brief explanation of the reason for the revision together with data indicating the scope of the investigations substantiating the recommendations. The standards affected are listed in Table I.

These recommendations have been submitted to letter ballot of the committee which consists of 84 voting members, the results being given in Table I.

ACTIVITIES OF SUBCOMMITTEES

A large part of the work of the subcommittees during the year has consisted in obtaining data and studying results with a view to improving the present standards and developing new standards. In any one year only a small portion of the work can result in definite recommendations. It is felt desirable, therefore, to mention briefly some of the other projects which have engaged the attention of the subcommittees, but which as yet have not reached the stage where definite standards have resulted.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee D-9 reported the following results of the letter ballot vote of a total of 54 ballots returned from a committee membership of 88: D 467 – 37 T, affirmative 28, negative 6, ballots marked "not voting" 20; D 468 – 37 T, affirmative 20, negative 7, ballots marked "not voting" 27; D 229 - 37 T, affirmative 32, negative 7, ballots marked "not voting" 15.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 973, 1008, 1027 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 966, 1015, 1115.

Subcommittee I on Insulating Varnishes, Paints and Lacquers (C. F. Hanson, chairman).—The study of the bonding properties of saturant varnishes is being continued. Some progress has been made in developing a method of test for "set time" of phenolic resin varnishes. Information is being collected with a view to developing a method of test for acid and alkali resistance of varnishes. Work is continuing in an attempt to develop methods of test for electrical properties of shellac.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Method of Testing Solid Electrical Insulating Materials for Arc Resistance	27	0	16
Method of Acetone Extraction of Phenolic Molded or Laminated Products	25	0	18
II. REVISIONS OF TENTATIVE STANDARDS			
Methods of Testing Varnishes Used for Electrical Insulation (D 115 - 36 T)	22	0	21
Methods of Testing Sheet, Tape, and Molded Insulating Materials for Dielectric Strength (D 149 - 36 T)	34	0	9
Methods of Testing Untreated Paper Used in Electrical Insulation (D 202 - 36 T)	22	0	21
Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 - 37 T)	29	0	14
Methods of Testing Varnished Cloths and Varnished Cloth Tapes Used in Electrical Insulation (D 295 - 37 T)	25	0	17
Methods of Testing Laminated Tubes Used in Electrical Insulation (D 348 - 35 T)	28	0	15
Methods of Testing Flexible Varnished Tubing Used for Electrical Insulation (D 350 - 37 T)	24	0	19
III. TENTATIVE REVISIONS OF STANDARDS			
Methods of Testing Molded Materials Used for Electrical Insulation (D 48 - 37)	26	0	17
Methods of Testing Pasted Mica Used in Electrical Insulation (D 352 - 36)	19	0	24
IV. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T), as revised	28	0	15
Methods of Test for Insulation Resistance of Electrical Insulating Materials (D 257 - 37 T), as revised	35	1	7
Methods of Test for Grading Natural Mica (D 351 - 36 T)	28	0	25
Methods of Testing Molding Powders Used in Manufacturing Molded Electrical Insulators (D 392 - 35 T)	21	0	22

During the coming year the committee plans to undertake work on two projects: (1) to define and classify organic coating materials, and (2) the development of specifications for a cabinet to be used in determining the drying time of air-drying varnishes.

Subcommittee II on Molded Insulating Materials (W. A. Evans, chairman).—The work in connection with the establishment of the standard test method for determining the shrinkage of molding material from the mold dimensions is still in progress.

Work has been undertaken to establish the design and dimensional requirements for molds to produce the standard test specimens prescribed in the Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 - 37) and in the Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T). A mold capable of producing five ½ by ½ by 5-in. test bars is being circulated among five different laboratories, and information has been collected by these laboratories to determine the possibility of adopting it as a standard mold. Data on the molding technique and condition will also be obtained. It is possible that the work on this one mold may be completed before the end of the year.

Repeated impact is an exceedingly important quality to study. However, its progress has of necessity been rather slow because of the expense and time required to design and build a satisfactory repeated impact machine.

It is realized that some of the newer and softer thermoplastics will need to be investigated in order to establish conditioning methods for the test specimens and specific conditions for testing the material. This work is being undertaken and when completed the expanded method will be added to Tentative Methods D 256 – 34 T.

Subcommittee III on Plates, Tubes, and Rods (Dean Harvey, chairman).—During the past few years an extensive study has been made of the effect of preconditioning of test specimens of laminated phenolic products upon the values and uniformity of results obtained. A recommended procedure for conditioning is nearly ready for submission to the committee.

Specifications for laminated phenolic tubes for radio use are also in course of preparation.

Tests are being made to compare the Rockwell hardness test on heated specimens of laminated phenolic products as an indication of punching quality, with actual punching in a die. A study is being made of the application of the Rockwell hardness test to additional materials for which it is not now specified.

Work is under way in cooperation with the U. S. Navy Department to develop test methods for product uniformity, and an extensive program of tests has been prepared. A study is being made of the accuracy and reproducibility of results that can be expected with the various methods of test, preliminary to including such information in the various standards.

Subcommittee IV on Insulating Mineral Oils (E. A. Snyder, chairman).—After a study of the saponification test it was decided that, since it was necessary to increase the time of digestion to approximately the same time recommended in the Standard Method of Test for Saponification Number (D 94 – 36) rather than have two methods for the saponification test, Committee D-2 on Petroleum Products and Lubricants, which has jurisdiction over Method D 94, should be asked to incorporate in Method D 94 the modifications in the procedure that needs to be followed in order to secure satisfactory tests on oxidized insulating oils.[1]

It has been suggested that the publication of a statement of the difficulties encountered in the electrometric titration method for determining neutralization number might aid in their solution since this would doubtless attract outside interests to the problem. It has also been suggested that a technical conference on the subject of electrometric titration be arranged at the time of the next meeting.

Section B on Sludge Testing has made a comprehensive review with consumers' representatives of the performance of insulating oil. As a result a new program will be prepared for the committee's consideration. A paper by F. M. Clark on "Studies in the Oxidation of Mineral Transformer Oil"[2] is being presented at this annual meeting of the Society.

Samples of high- and low-gas-content oils have been submitted to different members for round-robin tests; it is expected that the results of these tests will be received in time for discussion at the annual meeting.

A new section will probably be formed during the year to study the possibilities of developing an evaporation test applicable to insulating oils.

Subcommittee V on Ceramic Products (Porcelain, Glass, Etc.) (L. E. Barringer, chairman).—A study is being made of methods of testing porcelain for porosity by means of the die penetration method. The Standard Methods of Testing Electrical Porcelain (D 116 - 34) have also been reviewed with reference to the testing of steatitic and titanium bodies, and studies are now under way relating particularly to power factor and dielectric constant measurements of this class of materials. Special attention is being given to the electrode requirements.

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[1] See Editorial Note, p. 426.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 507 (1938).

This year has seen the completion by two more laboratories of electrical tests made on glass samples sent out in a round robin. The tests consist of making power factor and dielectric constant measurements on samples of five different glasses over a wide range of frequencies. So far five of the six laboratories in the round robin have measured the samples and submitted data.

Subcommittee VII on Electrical Tests (J. A. Scott, chairman).—The oil cell being purchased through the Research Fund of the Society is now ready and will be circulated in the subcommittee for round-robin tests.

A study is being made of the application of the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (D 150 - 36 T) to liquids and to all solid electrical insulating materials. Active projects include the measurement of power factor of mica splittings, and the measurement of power factor parallel and perpendicular to the laminations of solid insulations.

A study is also being made of the effect of rate of rise of voltage on dielectric strength tests and further coordination of dielectric strength testing. Measuring circuits and technique for power factor measurements on electrical insulating materials at ultra high frequencies, 1 megacycle and above, are being developed.

Subcommittee VIII on Insulating Papers and Fabrics (Treated and Untreated) (R. W. Chadbourn, chairman).—Division I on Untreated Paper has revised the colorimetric method of determining acidity or alkalinity of untreated paper. This method has limitations for acid papers, and for this type of paper it is proposed to develop, if possible, a satisfactory electrometric method. In the study of oil penetration, a satisfactory test apparatus has been developed and only a few details of the test technique remain to be determined. The division is proceeding to coordinate its activities with those of the new Committee D-6 on Paper and Paper Products before reviewing further some of the mechanical test methods.

A detailed study is being made of the newly developed machinist's micrometer with controlled spring, as well as the dial-type instrument. A study is also being made of the effects of creasing and elongation upon the dielectric properties of tape. The relation between smoldering and the application of high temperatures for short periods to varnished tubing is being investigated.

Subcommittee IX on Mica Products (M. P. Davis, chairman).—Three of the laboratories participating in the round-robin tests on the measurement of power factor and dielectric constant of natural mica show reasonably close agreement and a summary of the data will be presented to the committee upon the completion of the tests.

Color plates of various samples of mica show that they are satisfactory for grading. Through the Research Fund of the Society color plates are to be prepared to serve as reference standards for the Tentative Methods of Test for Grading Natural Mica (D 351 - 36 T).

A study is being made of various purchase specifications for mica.

Subcommittee X on Conditioning (Robert Burns, chairman).—As a result of studies of indoor atmospheric data over a substantial portion of the country, 40 per cent relative humidity at 25 C. was established as a definition of average room conditions.

A study of suitable atmospheric influences for the resistivity test was made. As a result of this work, 90 per cent relative humidity at 35 C. was recommended for the insulation resistance test, and 35 C. for the volume resistivity test, relative humidity being unimportant in the latter case.

Special Subcommittee on Significance of Tests (Dean Harvey, chairman).—In addition to the sections on dielectric strength test, resistivity test, and impact test published last year[1] as part of the report on Significance of Tests of Electrical Insulating Materials, sections have been prepared covering power factor, and tensile strength. These additional sections appear in Appendix II to this report.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 84 voting members; 43 members returned their ballots, of whom 37 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

T. SMITH TAYLOR,
Chairman.

E. J. RUTAN,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 436 (1937).

EDITORIAL NOTE

Subsequent to the annual meeting, Committee D-9 on Electrical Insulating Materials presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Revision of Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 38 T),

Proposed Revision of Tentative Method of Testing Pin-Type Lime Glass Insulators (D 468 – 37 T), and

Withdrawal of Tentative Method of Test for Saponification Number of Electrical Insulating Oils (Modified Baader Method) (D 438 – 36 T) which was replaced by a new Tentative Method of Test for Saponification Number (D 94 – 38 T), recommended jointly with Committee D-2 on Petroleum Products and Lubricants.

These recommendations were accepted by Committee E-10 and the new and revised methods appear on pp. 1046, 1037, and 881, respectively.

APPENDIX I

RECOMMENDATIONS AFFECTING STANDARDS FOR ELECTRICAL INSULATING MATERIALS

In this Appendix are given recommendations affecting certain standards and tentative standards covering electrical insulating materials which are referred to earlier in this report. In connection with each title is given the reference to the publication in which the standard appears in its present form.

New Tentative Standards

Tentative Method of Test for Arc Resistance of Solid Electrical Insulating Materials:

This method of test for determining the resistance of molded and laminated phenolic materials to arcing has already been in commercial use to a limited extent and has been found useful, especially in comparing the arc resistance of different materials. After considerable testing in several laboratories, the committee is recommending that this method be accepted for publication as tentative, as appended hereto.[1]

Tentative Method of Test for Acetone Extraction of Phenolic Molded or Laminated Products:

Some years ago it was found that uncured bakelite could be reacted upon by acetone, creating a staining of the acetone solution in which the incompletely cured part was immersed. This led many molders to believe that it could be used as a test for curing. However, the work of the committee has demonstrated that it is not a reliable test for curing but that an acetone extraction test, as outlined in the new method, could be used as a reliable identification test. The committee accordingly recommends this method for publication as tentative, as appended hereto.[1]

Revisions of Tentative Standards

Tentative Methods of Testing Varnishes Used for Electrical Insulation (D 115 - 36 T):[2]

It has been called to the attention of Subcommittee I on Insulating Varnishes, Paints and Lacquers, that the thickness tolerance stated in the various methods of testing insulating varnishes is much more precise than can be attained in actual practice. In order to overcome this criticism, it is proposed to add to Methods D 115 a new Section 8 which refers for thickness measurements to the Tentative Methods of Test for Thickness of Solid Electrical Insulation (D 374 - 36 T).

It is also proposed to revise all the methods in reference to thickness tolerances so that they will be within attainable accuracy. In addition to this, a few changes of an editorial nature are being made in the text of the various methods.

Revisions are also recommended in the dielectric strength test of varnish in the solid state described in Sections 12 to 16, the dielectric strength test of varnish in the liquid state described in Sections 35 to 39, and in Appendix II covering dielectric strength tests on copper base, the reasons for these revisions being as follows: It has been found that there is considerable variation among various laboratories in the dielectric strength obtained on the same varnish. Through a series of interlaboratory tests it was found that a large factor contributing to this variation is the question of the film thickness of varnish applied to each side of the paper base. Another factor is a matter of the baking time in preparing the specimens. The proposed revision is intended to eliminate these two factors to a large extent, by specifying a much closer tolerance on the thickness of the film of varnish built-up on each side of the sheet of paper and by providing for a more uniform time of baking or drying the varnish film as agreed upon by the manufacturer, and the purchaser. The second reason for proposing the revision of this test is to have the method conform with the proposed general revision of the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (D 149 – 38 T) mentioned below. The committee accordingly recommends that the revised sections, appended hereto,[1] be accepted as a revision of Methods D 115 – 36 T to replace the present Sections 8 to 18, 21 to 23, 34 to 38, and Appendix II.

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[1] See pp. 998, 994.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1039 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 1167.

Tentative Methods of Testing Sheet, Tape, and Molded Insulating Materials for Dielectric Strength (D 149 - 36 T):[2]

The committee is presenting a complete revision of these methods, entitled, Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies, as appended hereto.[3] These methods cover all general matters of testing equipment, electrodes, method and rate of voltage application, and are intended as a general guide to which the various material test methods may refer. Containing a list of the A.S.T.M. methods for various electrical insulating materials which include tests for dielectric strength, revised Methods D 149 will serve as a guide to this type of testing.

Tentative Methods of Testing Untreated Paper Used in Electrical Insulation (D 202 - 36 T):[4]

The test for acidity or alkalinity has been improved and clarified by some changes and additions, such as a decrease in the size of burette to accommodate more closely the test sample, expression of the test results in general terms and the inclusion of a method of standardization of acid and alkali solutions. It is recommended that the present Sections 46 to 49 of Methods D 202 be replaced by new Sections 46 to 51, as appended hereto,[1] the remaining sections in the methods to be renumbered accordingly.

Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 - 37 T):[5, 6]

Due to the revision of the general methods of test for dielectric strength (D 149 – 36 T), mentioned above, it has been necessary to include certain details of the dielectric strength test in Methods D 229, as follows:

Section 3.—Add a new section as Section 3 on Thickness to read as follows, renumbering the subsequent sections accordingly:

3. (*a*) *On Test Specimens.*—In the test methods which follow, all thickness measure-

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[1] These new and modified sections have been incorporated in the revised methods which appear on pp. 1080 and 1015, respectively.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 918 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 1002.

[3] See p. 1001.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 933 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 1047.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1027 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1115.

[6] See Editorial Note, p. 426.

ments shall be made using a machinist's micrometer in the manner outlined under Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 - 36 T) of the American Society for Testing Materials.

(*b*) *On Large Sheets.*—In the factory, measurements of large sheets of material may be made by using a gage mounted on a yoke of sufficient size and rigidity to permit accurate measurements in the center of the sheet.

NOTE.—Results of comparative tests in several factories, measuring 36-in. square sheets by a variety of such devices, indicate that the trade is able to measure sheets $\frac{1}{32}$ and $\frac{1}{8}$ in. in thickness to an accuracy of 0.0015 in. (In the tests, σ, or root mean square deviations, of 0.0005 were obtained.)

Section 33.—Replace this section, which refers for the dielectric strength test to Methods D 149 - 36 T, by new Sections 34 to 39, as appended hereto,[1] renumbering the subsequent sections accordingly.

Section 43.—Change the last sentence of Paragraph (*a*) of this section, redesignated Section 49, to read as follows by the addition of the italicized words and the omission of those in brackets:

> It is important that the major load be [released immediately after it has been fully applied] *removed within 1 sec. after the crank handle mechanism has come to a stop.*

At the end of Paragraph (*c*) add two new sentences to read as follows:

> Care shall be taken that the weight arm does not descend far enough to rest on the lifting link or pin. If the arm rests on the link or pin, the load or penetrator should be changed.

Tentative Methods of Testing Varnished Cloths and Varnished Cloth Tapes Used in Electrical Insulation (D 295 - 37 T):[2]

As a result of a joint meeting with representatives of the Insulated Power Cable Engineers Association a compromise between the existing methods of step-by-step dielectric strength was evolved. Due to the revision of the general method of test for dielectric strength (D 149 - 36 T), mentioned above, it has been necessary to include other details for the dielectric strength test in Methods D 295.

The present test for dielectric strength in Sections 15 and 16 is being replaced by a new dielectric strength test which will be described in Sections 15 to 20. The present Section 17 remains unchanged and will be redesignated Section 21. A new test will be added for endurance dielectric strength which will appear in Sections 22 to 25. An appendix is being added to the methods covering apparatus for making dielectric strength tests. This new and revised material is appended hereto.[1]

Tentative Methods of Testing Laminated Tubes Used in Electrical Insulation (D 348 - 35 T):[3]

Due to the revision of the general methods of test for dielectric strength (D 149 - 36 T), mentioned above, it has been necessary to include certain details of the dielectric strength test in Methods D 348. The present Sections 14 to 17 covering dielectric strength are being replaced by new Sections 14 to 21, as appended hereto,[1] the remaining sections being renumbered accordingly.

Tentative Methods of Testing Flexible Varnished Tubing Used for Electrical Insulation (D 350 - 37 T):[4]

Due to the revision of the general methods of test for dielectric strength (D 149 - 36 T), mentioned above, it has been necessary to include certain details for the dielectric strength test in Methods D 350. The present Sections 8 to 11 covering dielectric strength are being replaced by new Sections 8 to 13, as appended hereto,[5] the remaining sections being renumbered accordingly.

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[1] These new and modified sections have been incorporated in the revised methods which appear on pp. 1046, 1061, and 1009, respectively.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1047 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1152.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1030 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1033.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1056 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1161.

[5] These new sections have been incorporated in the revised methods which appear on p. 1074.

Tentative Revisions of Standards

Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 - 37):[1]

Due to the revision of the general methods of test for dielectric strength (D 149 - 36 T), mentioned above, it is necessary to include in Methods D 48 also, certain details of the dielectric strength test. The committee accordingly recommends that the new sections as appended hereto,[2] be accepted for publication as a tentative revision of Methods D 48.

Standard Methods of Testing Pasted Mica Used in Electrical Insulation (D 352 - 36):[3]

As a result of various comments to the effect that the load specified in Section 9 (*d*) is not sufficient, the committee is recommending a change in this section, as indicated below. Also, due to the revision of the general methods of test for dielectric strength (D 149 - 36 T), mentioned earlier in this report, it is necessary to include in Methods D 352 certain details of the dielectric strength test. The committee accordingly recommends that the changes as appended hereto,[4] be accepted for publication as a tentative revision of these methods.

Adoption of Tentative Standards as Standard

Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T):[5]

These methods have been in satisfactory use for the past four years without revision and the committee accordingly recommends, that with the minor revision in Section 3, as given below, the methods be approved for reference to letter ballot of the Society for adoption as standard.

Section 3 (d).—Change this section to read as follows by the addition of the italicized words and the omission of the word in brackets:

> (*d*) The striking edge of the pendulum shall be an [unrounded] edge ***having corners rounded to 1/32-in. radius*** formed, in the position of impact, by the intersection of a plane inclined away from the specimen at an angle of 5 deg. from the vertical with another plane perpendicular to the specimen, and shall be so aligned as to make contact across the full width of the specimen. In the striking position the striking edge shall be 0.866 in. from the edge of the specimen clamp.

Tentative Methods of Test for Insulation Resistance of Electrical Insulating Materials (D 257 - 37 T):[6]

These methods were issued last year as a revision of the Standard Methods of Test for Resistivity of Insulating Materials (D 257 - 33). During the year the revised procedure has been found very satisfactory and the committee has made a few further improvements in the methods including the addition of a diagram showing the application of electrodes in the case of tubular specimens, and a simplification of the electrical connections for the determination of insulation resistance. These several changes have been incorporated in the revised methods, appended hereto,[7] which the committee recommends for approval for reference to letter ballot of the Society for adoption as standard to replace the existing Standard D 257 - 33.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 232.

[2] See p. 1338.

[3] 1936 Book of A.S.T.M. Standards, Part II, p 1216.

[4] See p. 1338.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 995 (1934); also 1937 Book of A.S.T.M. Tentative Standards, p. 1023.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1016 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1102.

[7] These revised methods of test were adopted as standard by the Society and appear in the 1938 Supplement to Book of A.S.T.M. Standards, p. 174.

Tentative Methods of Test for Grading Natural Mica (D 351 - 36 T),[1] and Tentative Methods of Testing Molding Powders Used in Manufacturing Molded Electrical Insulators (D 392 - 35 T):[2]

The committee recommends that these tentative methods be approved for reference to letter ballot of the Society for adoption as standard.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 931 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 1038.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1037 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1040.

APPENDIX II

SIGNIFICANCE OF TESTS OF ELECTRICAL INSULATING MATERIALS

Significance of the Tensile Strength Test of Molded Materials

Scope of Method:

The method of testing the tensile strength of molded materials as described in the Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 37)[1] applies to hot-molded materials and plastic cold-molded materials. The specimen illustrated in Fig. 1 of D 48 – 37 is suitable for these two materials but is unsuited for the non-plastic inorganic cold-molded materials. A specimen suitable for these latter materials is under consideration. Two thicknesses of the specimen $\frac{1}{8}$ in. and $\frac{1}{4}$ in. are permissible. As values obtained by these two specimens may be different, the specimen is selected which is considered to be most representative of the material and its use.

Synopsis:

The tensile strength of a molded material may be defined as the number of pounds pull per square inch cross-section required to break the specimen. It is obtained by dividing the total load in pounds required to pull the specimen apart by the area of cross-section of the specimen in square inches at the point at which the specimen breaks.

The tensile strength values may vary with the thickness of the molded piece and with the temperature and the moisture content of the specimen. The tensile strength obtained by use of the standard molded specimen will not agree with that obtained by means of a specimen of the same shape but which has been machined from a thick molded piece. The value obtained for a given material by use of the molded piece will be much higher than that obtained with the machined specimen. This is due to the fact that the conditions of flow and cure are not the same when the standard specimen is molded as they are when a thick piece of material is molded.

The shape of the present tension test specimen was determined as a compromise in order to insure that the specimen would break at the reduced section and not be influenced by the clamping action of the jaws as was the case with the previous figure-eight specimen. It is quite likely that a specimen which is round in cross-section and would change by a large radius of curvature, from a reduced midsection to enlarged ends by means of which it is held, would be a more satisfactory specimen than the present one shown in Fig. 1. Such a specimen does not lend itself readily to the molding operations and hence the present flat specimen was developed.

It is therefore not possible to use the exact value of the tensile strength obtained by means of the molded specimen in estimating the tensile strength of the material in a piece having a thick cross-section. However, the values of tensile strength obtained by use of the test specimen can be used to give an indication of the relative tensile strengths to be expected in a finished molded article

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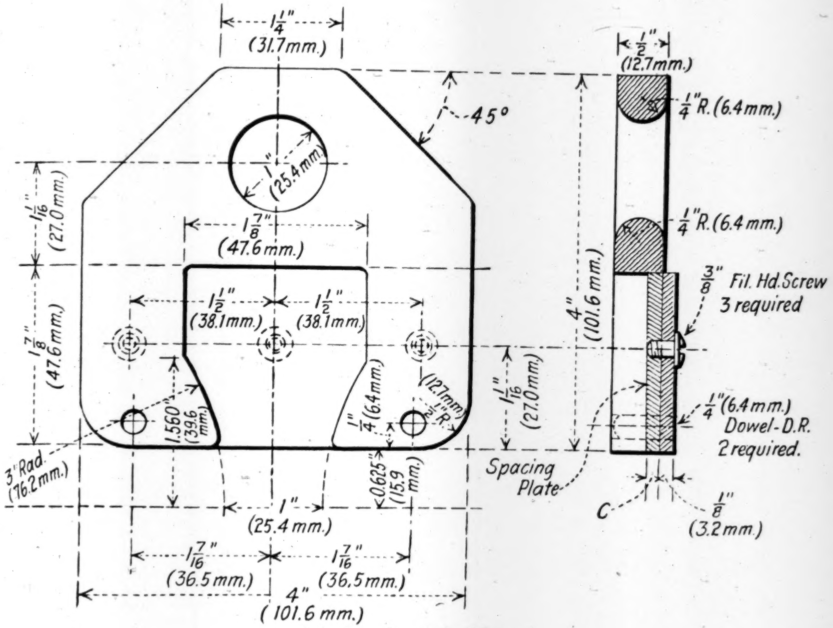
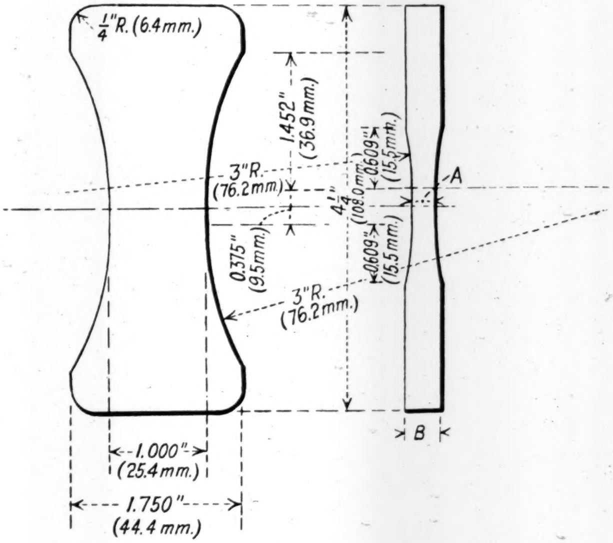
[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 232.


1 1/4" (31.7 mm.)
45°
1" (25.4 mm.)
1 1/16" (27.0 mm.)
1 7/8" (47.6 mm.)
1 1/2" (38.1 mm.)
1 1/2" (38.1 mm.)
1 7/8" (47.6 mm.)
1.560" (39.6 mm.)
1/4" (6.4 mm.)
(12.7 mm.) 1/2" R.
3" Rad. (76.2 mm.)
0.625" (15.9 mm.)
1" (25.4 mm.)
1 7/16" (36.5 mm.)
1 7/16" (36.5 mm.)
4" (101.6 mm.)
1 1/16" (27.0 mm.)
4" (101.6 mm.)
1/2" (12.7 mm.)
1/4" R. (6.4 mm.)
1/4" R. (6.4 mm.)
3/8" Fil. Hd. Screw 3 required
1/4" (6.4 mm.) Dowel-D.R. 2 required.
Spacing Plate
C
1/8" (3.2 mm.)

(*a*) Specimen holder.


1/4" R. (6.4 mm.)
1.452" (36.9 mm.)
3" R. (76.2 mm.)
0.375" (9.5 mm.)
4 1/4" (108.0 mm.)
0.609" (15.5 mm.)
0.609" (15.5 mm.)
A
3" R. (76.2 mm.)
B
1.000" (25.4 mm.)
1.750" (44.4 mm.)

(*b*) Tension test specimen.

	A	B	C
For 1/8-in. specimen	0.125 in. (3.2 mm.)	0.250 in. (6.3 mm.)	0.125 in. (3.2 mm.)
For 1/4-in. specimen	0.250 in. (6.3 mm.)	0.375 in. (9.5 mm.)	0.062 in. (1.6 mm.)

FIG. 1.—Tension Test Specimen and Holder.

NOTE.—To permit the use of one mold for all molding compounds the following variations in dimensions of the test specimen will be permissible:

For hot-molded compounds	± 5 per cent
For cold-molded compounds	± 10 per cent

when made of different molded materials. The values can also be used to insure uniformity in the molded material.

Some Factors Affecting Tensile Strength and Conditioning of Test Specimens:

The two chief factors affecting the value of the tensile strength at the time the tests are made are the temperature and the humidity to which the test specimens have been subjected. For those materials which readily absorb moisture, a variation in atmospheric humidity will affect the amount of moisture present in the material. For materials which are normally dry the addition of moisture will tend to increase the tensile strength. This is particularly true of all materials containing cellulose fillers, as cellulose readily absorbs moisture and its tensile strength is affected by this absorption. A variation in temperature will affect the moisture retained in the specimen and may also affect the nature of the binding agent. While in molded materials the resins are presumed to be thermosetting, it is true that, now when the rate of curing is so rapid and the time the material is being cured in the mold is relatively short, the resin is really made more flexible by an increase in temperature and hence the tensile strength would also be affected.

If the test specimens should be of the thermoplastic materials the temperature at which the tests are made are of much more importance than for thermosetting materials. As yet, these tests have not been adopted for thermoplastic materials but it is quite likely that they will be used for them while the subject is being studied. Hence the reason for this statement. For these reasons it is quite important that the specimens be conditioned immediately before the tests are made in order that the variations arising from differences in temperature and moisture content may be eliminated. The conditioning of the specimen should be done before testing by drying in an oven at 50 ± 5 C. (122 ± 9 F.) for 48 hr. followed by cooling to room temperature in a desiccator.

Usefulness of Tensile Strength Results:

The values for tensile strength can be used in determining the relative merits of various materials for any given application. They will assist in determining the material likely to give the strongest piece so far as tensile forces in the finished article are concerned. The producer can use the tensile strength test to assist him in controlling the uniformity of his product, the uniformity of the qualities of his raw materials, to control his processes of manufacture of both resin and molding compound to improve his product, and to develop materials for special applications.

The consumer finds use for the tensile strength test to insure that he is getting a material of specified qualities, to assist him in determining the materials most likely to be satisfactory for use on special jobs, and to improve the quality of his finished product as well as produce a satisfactory product at a lower cost.

The engineer must be very cautious in using the results of tensile strength in designing apparatus since the tensile strength of the material as it exists in the molded article is very likely to be much less than the value obtained with the specimen which has been molded under what may be considered ideal conditions. There may be cases in which the tensile strength of the molded article would not be over 25 per cent (or even less than this) of those values obtained with the tensile strength specimen shown in Fig. 1 of Standard D 48 – 37.

SIGNIFICANCE OF THE TENSILE STRENGTH TEST OF SHEET AND PLATE MATERIALS USED IN ELECTRICAL INSULATION

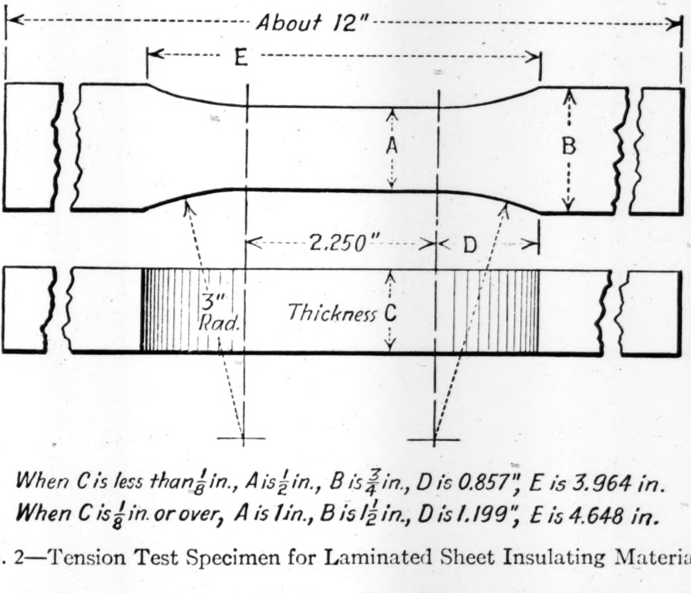
Scope of Method:

The methods of testing the tensile strength of sheet and plate materials used in electrical insulation as described in the Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 38 T)[1] is intended to apply to stiff, flat sheet and plate materials, such as phenolic and other types of laminated sheets, vulcanized fiber, hard rubber, asbestos composition board, and similar materials used as electrical insulation. As yet, a thorough study has not been made as to the applicability of the test to thermoplastic laminated materials, though it is likely that such studies will be made soon. In general, it may be assumed that the test will be found to be satisfactory for such materials.

Synopsis:

The tensile strength of sheet and plate material used in electrical insulation may be defined as the number of pounds pull per square inch cross-section required to break the specimen. It is obtained by dividing the total load in pounds required to pull the specimen apart by the area of cross-section of the specimen in square inches at the point at which the specimen breaks.

The test specimen is illustrated in Fig. 2. This shows that the specimen is always of the same dimension in one direction as the thickness of the plate from which it is cut. In the case of very thick plates which might be too thick to go into the jaws of the testing machine it would be permissible to saw the sheet along the laminations so as to have a piece which would not be too thick to be held in the jaws of the testing machine. The 3-in. radius of curvature was selected as being large enough practically to insure a break somewhere within the reduced section of uniform width and thickness instead of at the point where the curvature starts from the reduced



When C is less than $\frac{1}{8}$ in., A is $\frac{1}{2}$ in., B is $\frac{3}{4}$ in., D is 0.857", E is 3.964 in.
When C is $\frac{1}{8}$ in. or over, A is 1 in., B is $1\frac{1}{2}$ in., D is 1.199", E is 4.648 in.

FIG. 2—Tension Test Specimen for Laminated Sheet Insulating Materials.

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[1] See p. 1046.

section as was practically always the case when a small radius of curvature was used, such as 1 in.

The values of tensile strength of phenolic laminated materials are definitely affected by moisture and temperature. Moisture changes affect it because the sheets of paper or cloth run continuously throughout the length of the sheet and the path of the water through this cellulose layer is not broken up by resin barriers. Considerable change in temperature will also affect the tensile strength, as in most phenolic laminated materials the addition of heat causes a slight softening of the resinous binder which because of its nature is not permanently set by the molding operations. Vulcanized fiber is particularly affected by water absorption, and hard rubber on the other hand is more affected by temperature changes. There is no one set of conditioning which will apply the same to all these classes of materials. The conditions applicable to molding compounds will be quite satisfactory for laminated phenolic and vulcanized fiber materials, whereas, for hard rubber it will only be necessary to make the tests at a definite temperature without previous conditioning.

Usefulness of Tensile Strength Results:

The producer can use tensile strength results for the following:

1. To control the quality of his product.
2. To control the quality of his raw materials.
3. To improve his processes so as to produce higher quality with given raw materials and to reduce the cost of production.
4. To develop new materials and special materials for special applications.

The consumer can utilize tensile strength values for the following purposes:

1. To control the quality of the material he is purchasing.
2. To ascertain whether the material is suitable for a given application.
3. To design and make better and cheaper products.
4. To ascertain whether the material can be used satisfactorily in place of some other type of material which has thus far been used in certain applications.

SIGNIFICANCE OF THE POWER FACTOR TEST

Synopsis:

The power factor of a dielectric is a measure of the energy loss in an alternating electric field. In some applications of dielectrics it is important that the loss be as small as possible. In others, the loss is not intrinsically important, but its uniformity from specimen to specimen is a measure of the uniformity in manufacture. A measurement of power factor, therefore, is essential to a proper evaluation of dielectrics for insulating purposes; it is readily made for most of the ordinary frequencies, but unless proper attention is paid to the experimental conditions, it is possible to have large discrepancies between different test results on the same material and the true value of the power factor may be masked by extraneous effects.

The Power Factor of a Dielectric:

When a sinusoidal alternating voltage is applied to a capacitor, the resulting current will have a small component in phase with the voltage. The phase angle θ between current and voltage will, therefore, differ from 90 deg. by a small amount δ known as the loss angle. The power factor of the dielectric is defined as $\cos \theta = \sin \delta$. For most dielectrics the angle δ is so small that we may put $\sin \delta = \tan \delta = \delta$, when δ is expressed in radians. The power factor is the fraction of the energy lost during a cyclic charging and discharging of a condenser formed by the dielectric. The amount of energy stored in the dielectric at a given field is proportional to the dielectric constant. The product of the power factor and the dielectric constant is, therefore, a measure of the actual loss in the dielectric and is known as the loss factor. (Strictly, the loss factor by definition is the product of the dielectric constant and the tangent of the loss angle.)

Scope of Test Methods:

The Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (D 150 – 36 T)[1] cover the determination of power factor of both solid and fluid insulating materials at frequencies ranging from 25 to 10,000,000 cycles per sec. They give definitions of principal terms, an outline of the theory of the test, and a description of measuring circuits, systems of shielding, arrangement of electrodes, and preparation of test specimens.

Range of Power Factor Values:

All dielectrics show energy losses in alternating electric fields. In gases under ordinary conditions, however, the losses are so small as to be practically negligible. In fact, condensers with gases as dielectrics (for example, air condensers) are used as loss-free standards in power factor measurements. In liquids and solids the power factor ranges from 0.1 to 0.00001 in order of magnitude, corresponding to a loss angle ranging from a few degrees to a second of arc, approximately. Table I shows some typical values of power factor at room temperature.

TABLE I.—POWER FACTOR VALUES AT ROOM TEMPERATURE.

Material	Power Factor at 60 Cycles	Power Factor at 10,000,000 Cycles
Transformer oil	0.00001	......
Rosin oil (50% rosin)	......	0.01
Wood resin	0.02	0.005
Kraft paper	0.005	......
Manila paper	0.005	......
Impregnated paper	0.003	......
Porcelain	0.02	0.006
Steatite, normal	0.006	0.002
Steatite, high frequency	0.001	0.0005
Glass	0.005	0.002
Glass	0.03	0.006
Pyrex	0.005	0.004
Mica	0.02	0.006
Mica	0.0003 (800 cycles)	0.0002 0.0002
Quartz	......	0.0001
Quartz, perpendicular to axis	0.0007 (50 cycles)	0.0007 (2 x 10^6 cycles)
Quartz, parallel to axis	0.002 (50 cycles)	0.0003 (2 x 10^6 cycles)
Rubber, 0 per cent sulfur	0.02	0.008 (3 x 10^5 cycles)
Rubber, 4 per cent sulfur	0.02	0.43
Phenolic resin, wood flour filler	0,04 to 0.02	0.01 to 0.1
Cellulose acetate plastic	0.07	0.14
Cibanite resin (aniline formaldehyde)	0.01 to 0.02 (50 cycles)	0.001 to 0.003
Polystyrene	0.0003	0.0003

Purpose of Power Factor Test:

The power factor is of interest primarily as a measure of the energy loss in the dielectric. In certain applications of insulating materials it is of the utmost importance to have low dielectric loss. This is especially true of high frequency work, and also in large power cable networks. In other cases the dielectric loss may not be important in itself but may be a valuable indication of the stability of the dielectric. Sometimes the power factor may furnish an indication of the deterioration and useful life under stress of a dielectric. It may also be used as an index of purity of a particular dielectric since it is very sensitive to changes in composition.

Sources of Errors in Measuring Methods:

The most important sources of errors in the measurement of power factor are stray fields, both electric and magnetic, and poor contact of the electrodes.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 955 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1071.

Systems of shielding have been worked out for the different measuring circuits (see the Tentative Methods D 150) which effectively eliminate the trouble so far as stray electric fields are concerned. The necessity of shielding extends, of course, also to the measuring leads to the specimen under test. Magnetic shielding is not so readily attained with simple means. Unwanted magnetic coupling may be reduced by a judicious arrangement of the measuring circuit; shields of high-permeability material or eddy current shields may be of use in certain cases.

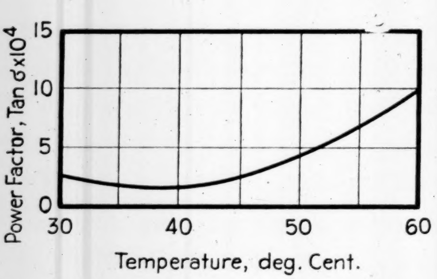

FIG. 3.—Impregnating Oil, 60 Cycles.

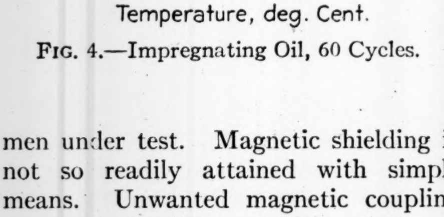

FIG. 4.—Impregnating Oil, 60 Cycles.

It is necessary that the electrodes make a close contact with the specimen; even minute air bubbles between the specimen and the electrodes will cause large errors in the value of power factor measured. Various means are employed to effect an intimate contact. Mercury electrodes seem to be most satisfactory for general use at all frequencies. When mercury electrodes are not practicable, tin-foil electrodes closely affixed to the specimen by means of a very thin layer of vaseline will give good results.

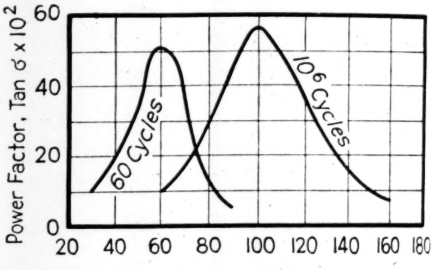

FIG. 5.—Wood Resin.

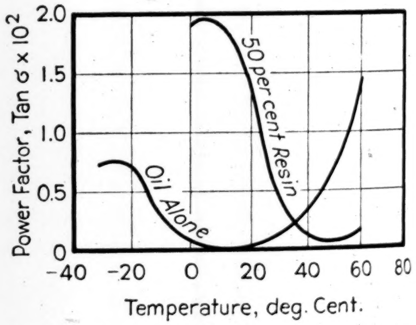

FIG. 6.—Cylinder Oil and Resin, 50 Cycles.

Influence of Test Conditions:

Electric Field.—At low values of the electric field there is at most a very small increase of the power factor or none at all as the field increases. But, if the field exceeds that at which ionization begins, then the power factor may increase very rapidly with the field.

Frequency.—Since dielectric loss is essentially a phenomenon occurring with alternating electric fields, it is to be expected that the value of the power factor will depend on the frequency. This is actually the case as is shown in Table I, for example, where the power factor of some materials is given both for power frequencies and radio frequencies. In general, the power factor decreases with increasing frequency over this range, but for some materials the change is in the other direction. If the loss is very small then the change with frequency is usually small (see values for polystyrene and quartz in Table I).

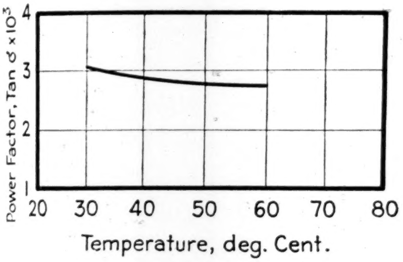

FIG. 7.—Impregnated Paper, 60 Cycles.

Temperature.—The power factor for most dielectrics varies quite rapidly with the temperature. Figures 3 to 8 show the relation between power factor and temperature for various substances at different values of frequency. In some cases the power factor passes through an extreme value as the temperature varies. The maximums may be quite sharp; their location depends on the frequency at which the measurements are made, and a study of them may yield valuable clues regarding the type of mechanism responsible for the dielectric loss.

Moisture.—Traces of moisture in a dielectric or on its surface may cause a considerable increase in the power factor value. The amount of moisture depends on the humidity of the atmosphere and the length of time the dielectric has been exposed to it.

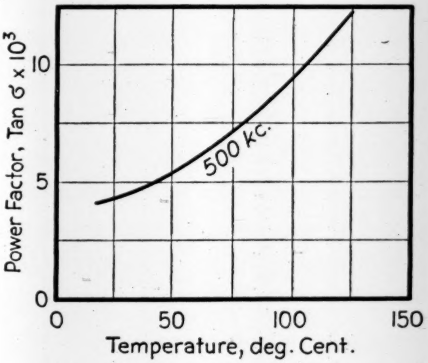

FIG. 8.—Pyrex Chemical-Resistance Glass.

Summing up what has been said about the influence of the test conditions, it may be stated that it is important to perform the power factor test with carefully controlled or specified values of frequency, temperature, and atmospheric humidity.

REPORT OF COMMITTEE D-11
ON
RUBBER PRODUCTS

Committee D-11 on Rubber Products has held one meeting during the year in addition to the one held at the 1937 annual meeting. This was in Rochester, N. Y., on March 9, 1938, in connection with the spring group meetings of A.S.T.M. committees. Meanwhile, the work of the committee has been carried on by correspondence and satisfactory progress has been made.

At the annual meeting last year, organization was authorized of two new subcommittees. Subcommittee XXII on Tests of Sponge Rubber Products is in process of organization under the chairmanship of L. P. Gould. Subcommittee XXIII on Tests of Hard Rubber Products, under the chairmanship of W. H. Juve, has completed its initial organization and started active work at the time of the spring meeting. Both of these subcommittees are receiving excellent response, indicating that they will fill a definite need in their respective fields.

A number of changes in the chairmanships of subcommittees have been necessitated during the year by the resignations of the former chairmen. William Staniar replaced W. L. Sturtevant as chairman of Subcommittee VI on Packings, Gaskets and Pump Valves; W. H. S. Youry is now chairman of Subcommittee IX on Insulating Tape, replacing M. F. Skinker; J. H. Ingmanson has replaced A. R. Kemp as chairman of Subcommittee XV on Life Tests; and E. B. Curtis is now chairman of Subcommittee XVIII on Dynamic Fatigue Testing, in place of W. L. Sturtevant. In addition, S. Collier has been appointed chairman of Subcommittee VIII on Nomenclature and Definitions.

Several changes have been made among company representatives in the committee. W. J. Harris replaced H. S. White of the Studebaker Corp.; S. M. Martin, Jr., replaced H. R. Ferguson of the Thiokol Corp.; and J. B. Evans of the Westinghouse Airbrake Co., is replacing H. C. Loudenbeck who is retiring from active service. Frank Gottsch has been appointed as representative of the New York City Central Testing Laboratory; and F. W. Sampson has been designated to represent the Society of Automotive Engineers, replacing Alex Taub.

New members who have been added to the committee during the year include the following: E. R. Dillehay, The Richardson Co.; L. Enderlin, Institut Français du Caoutchouc; H. J. Flikkie, The B. F. Goodrich Co.; T. S. Fuller, General Electric Co.; W. E. Glancy, Hood Rubber Co.; L. P. Gould, The B. F. Goodrich Co.; I. A. Hunt, Federal Products Corp.; D. E. Jones, American Hard Rubber Co.; W. H. Juve, Consulting Rubber Technologist; F. S. Malm, Bell Telephone Laboratories; C. P. Morgan, Vulcanized Rubber Co.; C. C. Rose, Willard Storage Battery Co.; and C. C. Wallace, Electric Storage Battery Co.

Committee D-11 has voted to cooperate in the standardization activities of the new International Committee on Rubber Products (I.S.A. 45) being organized under the International Standards Association. On the recommendation of Committee D-11, W. E. Emley and S. Collier have been appointed by the American Standards Association as the American representatives on this I.S.A. Committee. Committee D-11 was represented by R. P. Dinsmore at the International Congress on Rubber Technology held in London May 23 to 25, 1938. S. Collier and R. V. Yohe have been appointed to represent Committee D-11 on the Special Committee of Committee E-1, standardizing the softening point determination by the ring-and-ball apparatus.

Subsequent to the 1937 annual meeting, Committee D-11 presented to the Society through Committee E-10 on Standards a number of recommendations, including the following:

Tentative Specifications for:

Rubber Gloves for Electrical Workers on Apparatus or Circuits not Exceeding 3000 Volts to Ground (D 120 – 37 T), replacing Standard Specifications D 120 – 23,

Insulated Wire and Cable: Heat-Resisting Rubber Compound (D 469 – 37 T),

Tentative Methods of:

Testing Rubber Hose (D 380 – 37 T), replacing Standard Methods D 379 – 36 and D 380 – 36,

Testing Rubber Insulated Wire and Cable (D 470 – 37 T),

Test for Changes in Properties of Rubber and Rubber-Like Materials in Liquids (D 471 – 37 T),

Revised Tentative Specifications for:

Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 37 T), and

Insulated Wire and Cable: Performance Rubber Compound (D 353 – 37 T).

These recommendations were discussed in the 1937 annual report but were not ready at that time for submission to the Society; they were later thoroughly considered and approved by the committee. The recommendations were accepted[1] by Committee E-10 on August 26, 1937, and the new and revised tentative standards appeared in the 1937 *Proceedings*.[2]

During the year, on the recommendation of Sectional Committee C59 on Electrical Insulating Materials, the Tentative Specifications and Tests for Rubber Insulating Tape (D 119 – 35 T) were submitted to the American Standards Association. The specifications were approved as American tentative standard on January 5, 1938, and assigned the A.S.A. designation C59.6–1938.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

Tentative Methods of Testing Flat Rubber Belting.—These methods have been developed by Subcommittee II on Belting to provide a recommended procedure for testing all types of flat rubber belting. They are intended to amplify and replace the present Standard Methods of Testing Rubber Belting Used for Power Transmission (D 378 – 36). The present standard methods are limited to power transmission belting and contain no provision for tests of rubber covers on belts used for conveying and elevating materials. Since the methods of test of the body of these latter types of belting are similar to those for transmission belting, it has been possible to prepare, in a single standard, test procedures applicable to all flat types, by amplifying the present standard to include provisions for cover tests. The committee accordingly recommends that the Tentative Methods of Testing Flat Rubber Belting, appended hereto,[1] be accepted for publication as tentative to replace the Standard Methods of Testing Rubber Belting Used for Power Transmission (D 378 – 36) which are recommended to be withdrawn.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee D-11 reported the following results of the letter ballot vote of a total of 46 ballots returned from a committee membership of 87: D 120 – 37 T, affirmative 25, negative 0, ballots marked "not voting" 21; D 469 – 37 T, affirmative 31, negative 0, ballots marked "not voting" 15; D 380 – 37 T, affirmative 24, negative 0, ballots marked "not voting" 22; D 470 – 37 T, affirmative 31, negative 0, ballots marked "not voting" 15; D 471 – 37 T, affirmative 34, negative 1, ballots marked "not voting" 11; D 27 – 37 T and D 353 – 37 T, affirmative 31, negative 0, ballots marked "not voting" 15.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol 37, Part I, pp. 1062, 1096, 1153, 1166, 1148, 1070, 1109 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1187, 1232, 1339, 1352, 1334, 1206, 1245.

Revisions of Tentative Standards:

The committee is proposing revisions of three tentative methods of test and one tentative specification as indicated below and recommends that these tentative standards as revised be continued as tentative.

Tentative Methods of Physical Testing of Rubber Products (General Requirements) (D 15 – 35 T).[2]—For the sake of accurate definition, the committee recommends that the title of these methods of test be revised as follows:

Title.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> Tentative Methods of *Sample Preparation for* Physical Testing of Rubber Products [(General Requirements)].

Also, the following change is recommended in order to bring these methods into conformity with the best modern practice:

Section 8.—Omit the second sentence which reads as follows:

> If necessary to use gasoline, it shall be of a grade which distills below 302 F. (150 C.) and which, upon evaporation, does not leave an appreciable amount of oily residue.

Add, just prior to the last sentence, two new sentences to read as follows:

> If it is necessary to employ gasoline to effect the separation, it shall be straight-run gasoline of the quality known as aviation grade and shall have the following characteristics:
>
> | | |
> |---|---|
> | Specific gravity at 60 F. | 0.685 to 0.705 |
> | Distillation limits: | |
> | Initial boiling point | 100 to 120 F. |
> | 10 per cent evaporated | 128 to 143 F. |
> | 20 per cent evaporated | 140 to 155 F. |
> | 30 per cent evaporated | 150 to 164 F. |
> | 40 per cent evaporated | 156 to 174 F. |
> | 50 per cent evaporated | 164 to 184 F. |
> | 60 per cent evaporated | 173 to 194 F. |
> | 70 per cent evaporated | 182 to 207 F. |
> | 80 per cent evaporated | 193 to 223 F. |
> | 90 per cent evaporated | 209 to 245 F. |
> | 95 per cent evaporated | 224 to 260 F. |
> | Dry | 250 to 286 F. |
> | Recovery, min | 97 per cent |
>
> The gasoline shall contain no lead compounds and shall not leave an appreciable amount of oily residue when evaporated.

Tentative Methods of Testing Rubber Hose (D 380 – 37 T)[3].—These methods require that in the measurement of hose, thickness of a rubber element shall be determined by means of a micrometer having a presser foot $\frac{1}{4}$ in. in diameter exerting a force of 9 oz. on the specimen. In the case of fire hose, it is not customary in the trade to use this standard micrometer. The committee would prefer to avoid making exceptions to standardization principles but, unfortunately, any change in the present practice of testing fire hose might necessitate revision of the detailed requirements of purchase specifications already promulgated by a wide diversity of interests. It appears, therefore, that the present hose methods do not adequately cover standard practice in the measurement of thickness of fire hose. Since these methods are intended to be used for all types and constructions of rubber hose, the committee recommends that they be revised as follows:

Section 4 (a).—Change to read as follows by the addition of the italicized words and figures and the omission of the words in brackets:

> 4. (*a*) The thickness of a rubber element *from any type of hose except cotton rubber-lined fire hose* shall be determined by means of a

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[1] See p. 1105.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1153 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1260.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1153 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1339.

> *standard* micrometer graduated to thousandths of an inch and having a presser foot 0.25 in. ± 0.01 in. in diameter, exerting *under dead-weight load* a total force of 9 oz. ± 0.1 oz. [The load shall be applied by means of a weight.] *In the case of cotton rubber-lined fire hose, a spring gage micrometer provided with a presser foot 0.375 in. ± 0.01 in. in diameter, exerting a total force of 2.1 oz. (60 g.) ± 0.1 oz., shall be used.*

Tentative Methods of Testing Rubber Insulated Wire and Cable (D 470–37 T).[1,2] –The committee recommends two changes in these tentative methods. The first is a revision in the requirements of the transformer used in connection with voltage tests made with alternating voltage, as follows:

Section 11 (b).—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> (*b*) For tests with alternating voltage, there shall be used a transformer of such capacity that the [wave form is not appreciably distorted from] *crest factor (ratio of maximum to mean effective) of the test voltage shall not differ by more than plus or minus 10 per cent from that of* a sinusoidal [shape] *wave* when *the transformer is* loaded with the test specimen.

The second change consists in the addition to Tentative Methods D 470 of a test method for ozone resistance, as appended hereto. This method has had considerable study and has been in use for a number of years by members of the committee.

Tentative Specifications for Rubber Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 37 T).[3]—The revisions proposed in these specifications comprise: (1) a revision of the requirements on stranding of conductors to agree with current practice in the industry; (2) a simplification of the requirements for width and overlap of rubber-filled cable tape; and (3) an amplification of the procedure for measuring thickness of cotton braids. These changes, which are given in detail below, are considered by the committee as greatly improving the present specifications:

Section 5.—Change from its present form: namely,

> 5. The stranding shall conform to the requirements of Table I and shall be either standard concentric or flexible as specified in the order.

to read as follows:

> 5. The stranding shall conform to the Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (A.S.T.M. Designation: B 8, Table I, Class B, or where specified, Class C) of the American Society for Testing Materials. If a more flexible stranding is specified in the order, it shall conform to the requirements of the accompanying Table I.

Table I.—Change from its present form to read as follows:

TABLE I.—STRANDING OF INSULATED CONDUCTORS.

SIZE OF CONDUCTOR	FLEXIBLE STRANDING, NUMBER OF WIRES
No. 18 A. w. g.	16
No. 16 A. w. g.	26
No. 14 to No. 9 A. w. g.	37
No. 8 to No. 2 A. w. g.	49
No. 1 to No. 0000 A. w. g.	133
250 000 to 500 000 cir. mils	259
550 000 to 1 000 000 cir. mils	427
1 100 000 to 1 500 000 cir. mils	427
1 600 000 to 2 500 000 cir. mils	703

Table VII.—Under (C) Cable Tape, change Table VII from its present form to read as follows:

TABLE VII.—WIDTH AND OVERLAP OF RUBBER-FILLED CABLE TAPE.

DIAMETER OVER INSULATION, IN.	MAXIMUM WIDTH OF TAPE, IN.	MINIMUM OVERLAP, IN.	MINIMUM OVERLAP, PER CENT
0 to 0.250	$1\frac{1}{2}$	$\frac{3}{16}$	12.5
0.251 to 0.500	2	$\frac{1}{4}$	12.5
0.501 to 0.750	$2\frac{1}{2}$	$\frac{5}{16}$	12.5
0.751 to 1.00	3	$\frac{3}{8}$	12.5
1.001 to 1.500	4	$\frac{1}{2}$	12.5
1.501 to 2.000	5	$\frac{5}{8}$	12.5

Section 54.—Omit this section which reads as follows, renumbering the subsequent sections accordingly:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1166 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1352.

[2] See Editorial Note, p. 450.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1070 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1206.

54. For intermediate diameters the requirements shall be those of the next smaller diameter indicated in Table VII.

Section 59.—Change the paragraph on Thickness of Braid from its present form: namely,

> *Thickness of Braid* (2 × diameter of single end of cotton), by measuring 25 per cent of the total number of threads with a paper micrometer having a foot 0.4 in. in diameter under a weight of 50 g. The sample of braid on which the average diameter is determined shall be prepared by immersing a 2-in. length of sample in chloroform in a suitable container for 5 minutes, decanting and repeating for 1 minute, and removing and drying it thoroughly by pressing it between cheese cloth.

to read as follows:

> *Thickness of Braid.*—A sample of braid approximately 2 in. in length shall be carefully slit and removed from the completed wire and immersed in chloroform or other suitable solvent for 5 min. The solvent shall be decanted and the operation repeated until the cotton is substantially free of saturating and finishing material. The sample shall then be dried by pressing between blotting papers. The extracted sample shall be measured by means of a dial micrometer having a presser foot 0.4 in. in diameter and a weight on the sample of 50 g. Five readings shall be made at different points on the sample and the average taken as the thickness of the braid. In the case of a double braid, each braid shall be removed and measured separately.

Revisions of Standards:

The committee recommends for immediate adoption, revisions in two standards, as indicated below, and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that these modifications may be referred to letter ballot of the Society. These revisions are interrelated and should be made simultaneously.

Standard Methods of Chemical Analysis of Rubber Products (D 297 – 36).[1]—The following revisions are recommended in the Section on Methods of Analyses (A) Complete Procedure, in order to amplify the procedure now given:

Section 16.—Following the second sentence add two new sentences to read as follows:

> It is intended that these limits shall establish the minimum period for the extraction and they shall not be regarded as implying that the extraction must be discontinued immediately when the liquid in the thimble is colorless. When overnight extraction is more convenient, the additional period, after the liquid in the thimble is colorless, is not objectionable.

Section 22.—Designate this section covering the determination of ash as the Rapid Method.

New Section.—Add as a new Section 23, the Referee Method for determining ash given in Section 33 of the Standard Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 – 35),[2] renumbering the subsequent sections accordingly.

Section 35.—Add at the end of this section, covering calculation of acetone extract, a new sentence to read as follows:

> When the percentage of *organic* acetone extract is required, this shall be taken as the percentage of acetone extract, uncorrected, minus the percentage of free sulfur.

Standard Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 – 35).[2]—The following revisions are recommended in these specifications for the purpose of removing the reprinted detailed methods of test and replacing them with suitable references to the Standard Methods of Chemical Analysis of Rubber Products (D 297) and the Tentative Methods of Testing Rubber Hose (D 380 – 37 T). The revisions will obviate unnecessary reprinting and will aid in eliminating and avoiding inconsistencies in the current standards. The methods included at present in Specifications D 296 have been used with practically no revision for ten years. During the past several years,

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1249.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1221.

Subcommittee I on Hose has devoted considerable time and attention to a detailed study of methods of testing all types of rubber hose, including fire hose. The results of this work were incorporated last year in the Tentative Methods of Testing Rubber Hose (D 380 – 37 T) and it is felt that the fire hose methods, in so far as they diverge from the present recommended practice, should be brought into agreement.

Section 3 (d).—Change to read as follows by the addition of the italicized word and the omission of those in brackets:

> (*d*) Backing.—The backing, if used, shall not exceed 0.028 in. in thickness, as measured from the bottom of the corrugations. It need not be of the same composition as the rubber lining but the adhesion between the [rubber lining] *backing* and the cotton jacket shall conform to the requirements specified in Section 13.

Section 6.—Change from its present form: namely,

> 6. The chemical tests required by the following chemical requirements shall be made in accordance with the methods of testing described in Sections 22 to 35, inclusive.

to read as follows:

> 6. The analytical tests required by the chemical composition requirements in Section 7 shall be made in accordance with the Standard Methods of Chemical Analysis of Rubber Products (A.S.T.M. Designation: D 297) of the American Society for Testing Materials.

Section 8.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 8. The tests necessary to determine the physical properties which are specified in the following sections shall be made in accordance with the [methods of testing described in Sections 36 to 51, inclusive] *Tentative Methods of Testing Rubber Hose (A.S.T.M. Designation: D 380 – 37 T) of the American Society for Testing Materials, except as otherwise prescribed in these specifications.*

Sections 22 to 56.—Omit these sections covering the methods of testing fire hose.

Adoption of Tentative Standards as Standard:

Tentative Specifications and Tests for Friction Tape for General Use for Electrical Purposes (D 69 – 36 T).[1]—The committee recommends that these specifications be approved for reference to letter ballot of the Society for adoption as standard. The specifications have been in the tentative status for a number of years with frequent revision as required. They are in very general use and, for the past two years, no revisions have been considered necessary. The committee recognizes that tape meeting these specifications may not be entirely satisfactory in some special applications; thus, in railroad signal work, greater adhesion than the required minimum is often specified. The committee believes, however, that the present specifications satisfactorily cover, as intended, a tape "for general use for electrical purposes" and prefers to consider issuing separate specifications for special services, as required.

Tentative Specifications and Tests for Rubber Insulating Tape (D 119 – 35 T).[2]—The committee recommends that these specifications with the following minor revision be approved for reference to letter ballot of the Society for adoption as standard:

Section 17 (a).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 17. (*a*) A specimen 7 in. in length shall be taken from the roll, care being [taken] *observed* not to touch the surface to be tested with the hands or otherwise [and]. Two inches of the specimen *shall be* wound on [the] *a* mandrel, and then a weight of 4 lb. per inch of width of tape shall be attached to the end of the specimen. Should this weight [not be sufficient] *be insufficient* to elongate

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1059 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 1195.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1110 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1201.

the tape 200 per cent *or more*, additional downward force shall be applied by hand until [the desired] *200 per cent* elongation has been produced. The tape shall then be wound on the mandrel at a uniform rate of 12 in. per min. and allowed to stand for 3 min. with the weight attached. *Then, with the weight still attached*, [it] *the tape* shall [then] be allowed to unwind slowly [until the fused turns are reached]. The mandrel shall revolve not more than two and one-half turns [before the fused turns are reached] *in the first 2 min., during which time* the tape shall sustain the weight [for 2 min. without further unwinding] or shall break at the point of unwinding.

Withdrawal of Standard:

Standard Methods of Testing Rubber Belting Used for Power Transmission (D 378 - 36).[1]—The committee recommends the withdrawal of these test methods, as mentioned earlier in this report. These methods are being expanded to include belting used for conveying and elevating materials and are being reissued in amplified form as a new tentative standard, appended hereto,[2] entitled "Tentative Methods of Testing Flat Rubber Belting."

Tentative Standards Continued as Tentative:

The committee desires that all tentative standards under its jurisdiction that are not mentioned in this report be continued as tentative without revision, including the Tentative Specifications for Rubber Pump Valves (D 151 - 31 T) and the Tentative Methods of Test for Flexing of Rubber Products (D 430 - 35 T), both of which have had a tentative status for three years or more. These tentative standards are not being recommended for adoption at this time for the reasons given in the discussion of activities of subcommittees, mentioned later in this report.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 97 members; 70 members returned their ballots, the results being given in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARD			
Methods of Testing Flat Rubber Belting (D 378 - 38 T)	37	1	32
II. REVISIONS OF TENTATIVE STANDARDS			
Methods of Physical Testing of Rubber Products (General Requirements) (D 15 - 35 T)	62	0	8
Methods of Testing Rubber Hose (D 380 - 37 T)	38	2	30
Methods of Testing Rubber Insulated Wire and Cable (D 470 - 37 T)	48	0	22
Specifications for Rubber Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 - 37 T)	45	1	24
III. REVISIONS OF STANDARDS			
Methods of Chemical Analysis of Rubber Products (D 297 - 36), immediate adoption	52	2	16
Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 - 35), immediate adoption	37	1	32
IV. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications and Tests for Friction Tape for General Use for Electrical Purposes (D 69 - 36 T)	48	3	19
Specifications and Tests for Rubber Insulating Tape (D 119 - 35 T), as revised	52	0	18
V. WITHDRAWAL OF STANDARD			
Standard Methods of Testing Rubber Belting Used for Power Transmission (D 378 - 36)	37	0	33

ACTIVITIES OF SUBCOMMITTEES

Discussion of the activities of the D-11 subcommittees will be limited here to consideration of a few of the more important projects in progress. It should be understood, however, that all of the subcommittees are at present active in their respective fields.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1274.

[2] See p. 1105.

Subcommittee V on Insulated Wire and Cable (R. A. Schatzel, chairman).—This subcommittee expects to recommend, in the near future, revisions of the wire specifications[1] under its jurisdiction whereby the detailed test methods now contained therein will be deleted and replaced by suitable references to the newly revised Tentative Methods of Testing Rubber Insulated Wire and Cable (D 470 - 37 T). The subcommittee is also working on proposed specifications for rubber sheath compound for portable cords and cables. It was anticipated last year that these specifications would have been completed by this time but difficulty is being experienced in finding tests applicable to insulated wire which adequately measure the resistance of the insulation to abrasion and tearing. Investigations of these tests are being continued. The test section of the subcommittee is doing considerable work on an improved method of evaluating the effect of moisture absorption on electrical insulation. This section is also investigating another and perhaps simpler method for measuring ozone resistance.

Subcommittee VI on Packings, Gaskets and Pump Valves (William Staniar, chairman).—This subcommittee has reorganized during the year under a new chairman and has formulated a definite program for standardization work on valves and packings. In the field of packings, the subcommittee expects to limit its work for the present to the development and standardization of tests for products composed in part, at least, of rubber. Attention will be given to performance tests intended to evaluate the behavior in service as well as to the ordinary simple acceptance tests. The subcommittee is undertaking a survey by means of a questionnaire sent to both manufacturers and users whereby information will be obtained as to the extent of the present use of purchase specifications and methods of test for packings, the degree of standardization which now exists, and the activities which are most needed. With respect to valves, a section of the subcommittee is undertaking a study of the present Tentative Specifications for Rubber Pump Valves (D 151 - 31 T) to determine changes which may be required either to make the specifications suitable for adoption or to recommend other action.

Subcommittee X on Physical Testing of Rubber Products (H. M. Frecker, chairman).—The second edition of the compilation of "A.S.T.M. Standards on Rubber Products," which is under the jurisdiction of this subcommittee, was issued last fall. In the three years since this pamphlet was first issued, it has attained wide acceptance, both in this country and abroad, as the authoritative manual of methods for testing rubber products. Another effect of having this publication has been to stimulate standardization activities with the result that test methods have been improved and amplified and many new lines of investigation have been opened.

The subcommittee has conducted a cooperative program of tension testing in five laboratories. In general, the test program showed that where a single laboratory uniformly mixed and cured a rubber compound and prepared dumbbell specimens which were subsequently tested in the different laboratories, reasonably uniform tension test results could be obtained. This uniformity immediately disappeared when the different laboratories attempted to die out their own specimens. It was apparent, therefore, that more work by the committee on sample preparation is necessary and a section is being organized to proceed with this investigation.

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[1] The editorial rearrangement of the insulated wire and cable specifications was completed in 1938. The specifications in their latest form are printed in the 1938 Book of A.S.T.M. Tentative Standards, pp. 1245, 1259, and 1265.

The present method of interpreting and reporting results of tension tests, particularly with reference to the number of specimens, the selection of check tests, and the discarding of results, has been subject to some criticism. The questions involved are controversial, and it is certain that no single present procedure is uniformly acceptable. Since the tension test is probably the one most widely used, and uniform practice in handling the results is of great importance, the subcommittee has organized a section to make a complete study of this whole problem.

Subcommittee XI on Chemical Analysis of Rubber Products (S. Collier, chairman). —Among other activities, this subcommittee has been investigating colorimetric methods for the determination of small amounts of manganese and copper in rubber. These methods were recommended to the subcommittee by the Crude Rubber Committee, Division of Rubber Chemistry of the American Chemical Society. The inclusion in the Standard Methods of Chemical Analysis of Rubber Products (D 297) of methods for the determination of these metals is considered very desirable because of the serious effect of their presence even in very small amounts in hastening deterioration of vulcanized rubber products. Before recommending adoption of these particular methods, the subcommittee desired comparative data on their accuracy and reliability and that of the various other methods now in use. Accordingly, a cooperative test program has been carried out. Large samples of rubber containing known additions of copper and manganese were prepared at a central laboratory and portions were sent to the various members of the committee. These samples were analyzed, using the recommended A.C.S. methods, and also using any other method which the member wished to suggest. In this way, data have been accumulated on a considerable number of chemical and spectroscopic methods. The committee will have a complete report ready in the near future and hopes to be able to present final recommendations on the adoption of suitable methods. The committee is also concentrating on investigations of a number of other methods of chemical analysis, including those for sulfur and carbon black.

Subcommittee XIV on Abrasion Tests for Rubber Products (G. S. Haslam, chairman).—During the past year this subcommittee has brought to successful culmination a project of wide-spread interest and importance in the field of rubber testing, namely, the establishment of a source of standard reference test specimens for use in abrasion tests of rubber compounds made according to Method B of Tentative Methods of Test for Abrasion Resistance of Rubber Compounds (D 394 - 37 T). Work on this project has been in progress in the subcommittee for several years. The subcommittee members, cooperating with the laboratories of V. L. Smithers, Inc., have developed a test compound and procedure whereby the physical properties can be maintained reasonably constant in successive batches. The standard reference specimens are made from the compound given in Section 3 of Tentative Methods D 394 - 37 T as Comparison Standard B. The committee has established by cooperative testing that abrasion test specimens, properly prepared from this compound in a central supply laboratory and distributed to different laboratories, will consistently show a volume loss per horsepower hour of 200 cu.cm. ±5 per cent, when tested according to the A.S.T.M. method using standardized abrasive paper furnished with the specimens. The importance of this work in advancing the standardization of rubber testing can hardly be overemphasized because these reference specimens which are now commercially available provide a better medium for comparing and checking abrasion results in different laboratories than has ever been available heretofore.

Subcommittee X on Physical Testing hopes in the near future to be able to extend this work on standard reference specimens of rubber into the field of tension testing.

Subcommittee XV on Life Tests for Rubber Products (J. H. Ingmanson, chairman).—Following the acceptance last year of the Tentative Method for Air Pressure Heat Test for Vulcanized Rubber (D 454 – 37 T), this subcommittee has felt that investigation should be continued on further standardization of details of the test. A section has been organized to proceed with this work and is conducting a cooperative test program to determine the uniformity of aging in the various types of apparatus currently used in different laboratories. An investigation is also being made of the effect of moisture in the aging chamber with the intention of establishing, if advisable, a permissible humidity range for the test.

Many consumers and producers of rubber goods have expressed interest in methods for evaluating the aging and cracking of rubber exposed to light. There is at present very little standardization of methods for light tests and, since this problem is definitely within the scope of activity of this subcommittee, a section has been organized to survey laboratories relative to methods of light aging now used, and to formulate standard procedures for sunlight aging and sunlamp aging.

Subcommittee XVII on Rubber Products for Absorbing Vibration (J. J. Allen, chairman).—This subcommittee has been devoting considerable attention to the question of hardness determination. It is recognized that there is a definite need for the development and use of a small portable hardness testing instrument having greater reliability than existing instruments. A section of the subcommittee is now preparing an outline defining in detail the desired characteristics of such an instrument. When these specifications are completed they will be submitted to various instrument manufacturers and efforts will be made to develop an instrument.

Subcommittee XVIII on Dynamic Fatigue Testing for Rubber Products (E. B. Curtis, chairman).—The subcommittee has reviewed the Tentative Methods of Test for Flexing of Rubber Products (D 430 – 35 T), which are under its jurisdiction, with a view toward either recommending their adoption or revising them as may be desirable. A letter ballot of the subcommittee indicated that a revision of the methods would be required and the subcommittee plans to go ahead with this work at once.

Subcommittee XX on Adhesion Tests (A. H. Flower, chairman).—The subcommittee has made a comparative study of adhesion tests of rubber to metal, in which the separating force is applied to the adhered surface in direct tension, and those in shear. This work included tests using five different hardnesses of stocks and three different thicknesses of rubber sandwiched between the metal pieces. The results showed that with fairly hard compounds (A.S.T.M. hardness Nos. 26 to 50), specimens tested in the shear position give values of pull for separation which is the resultant of both shear and tension forces. A section about $\frac{3}{8}$ in. wide extending from the outer edge toward the center, appears to fail due to shear stresses, while the center section probably fails due to tension stresses. The stiffer stocks have a greater area resisting the shear forces. Soft stocks show less resistance to shear, thus reducing the failure area due to shear to a minimum and giving a larger area of failure due to tension. When using soft compounds in ½-in. sandwiches, tension and shear results are approximately the same. With harder stocks in both ⅛- and ½-in. sandwiches, the adhesion results are greater in the shear position than in the tension position. With very thin sandwiches, for example $\frac{1}{32}$ in., the results were erratic.

Subcommittee XXIII on Hard Rubber (W. H. Juve, chairman).—This subcommittee held its organization meeting in March, 1938, and formulated a list of important properties of hard rubber which should be investigated in the work of standardizing test methods. These properties are classified in three groups: namely, physical, chemical, and electrical. The properties included in each group are as follows:

Physical Group:

(*a*) Tensile strength and elongation,
(*b*) Transverse and deflection tests,
(*c*) Impact strength,
(*d*) Hardness,
(*e*) Cold flow,
(*f*) Softening point, effect of high and low temperature,
(*g*) Compressive strength,
(*h*) Coefficient of linear expansion,
(*i*) Thermal conductivity and flammability,
(*j*) Aging properties,
(*k*) Surface defects and appearance, and
(*l*) Machining properties.

Chemical Group:

(*a*) Acid absorption,
(*b*) Solubility in acids, resistance to chemical reagents and solvents,
(*c*) Chemical analysis, and
(*d*) Tarnishing effect.

Electrical Group:

(*a*) Dielectric strength,
(*b*) Surface resistivity,
(*c*) Power loss Factor,
(*d*) Arc resistance and carbonization, and
(*e*) Aging effects on electrical properties.

The subcommittee is divided into three sections, each of which will be responsible for one of the preceding groups of tests.

The election of officers for the ensuing term of two years resulted in the reelection of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 97 members; 70 members returned their ballots, of whom 67 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

O. M. HAYDEN,
Chairman.

ARTHUR W. CARPENTER,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee D-11 on Rubber Products presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Methods of Test for Resistance to Light Checking and Cracking of Rubber Compounds,
Proposed Revision of Tentative Methods of Testing Rubber Insulated Wire and Cable (D 470 – 38 T),
Proposed Tentative Revision of Standard Methods of Chemical Analysis of Rubber Products (D 297 – 38), and
Proposed Tentative Revision of Standard Method of Test for Hardness of Rubber (D 314 – 34).

These recommendations were accepted by Committee E-10 and appear on pp. 1139, 1127, 1332, and 1333, respectively.

REPORT OF COMMITTEE D-12
ON
SOAPS AND DETERGENTS

Committee D-12 on Soaps and Detergents held two meetings during the year, one on October 18–19, 1937, and the other on March 7–8, 1938, both at the Hotel New Yorker, New York City.

The present membership of the committee is 59, of whom 26 are classified as producers, 19 as consumers, and 14 as general interest members.

Mr. W. H. Koch was appointed chairman of Section D, Subcommittee I, to succeed Mr. J. D. MacMahon, who could not continue; Mr. G. P. Fulton to succeed Mr. G. G. Gaubatz, Jr. (resigned) as chairman of Section C, Subcommittee I and Section D of Subcommittee II; and Mr. J. C. Harris to succeed Mr. G. B. Hogaboom, as chairman of Section G, Subcommittee II.

It is recommended that the name of the committee be changed to read Soaps and *Other* Detergents, and that the title of Section C, Subcommittee I, be changed from Dry Cleaning Soaps to read Dry Cleaning Detergents.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

The committee recommends that the following four new specifications for soap and four new methods of test be accepted for publication as tentative, as appended hereto:[1]

Tentative Specifications for:

White Floating Toilet Soap, proposed by Section C, Subcommittee II,
Chip Soap, proposed by Section C, Subcommittee II,
Powdered Laundry Soap, proposed by Section C, Subcommittee II,
Ordinary Laundry Bar Soap, proposed by Section B, Subcommittee II, and

Tentative Methods of:

Test for Particle Size of Soaps and Other Detergents, proposed by Section A, Subcommittee I,
Determination of Combined Sodium and Potassium Oxides in Soaps proposed by Section A, Subcommittee I,
Chemical Analysis of Sulfonated (Sulfated) Oils, proposed by Section B, Subcommittee I, and
Chemical Analysis of Special Detergents, proposed by Section D, Subcommittee I.

Revisions of Tentative Standards:

The committee recommends that the following two tentative specifications and list of definitions be revised as set forth in the reports of the subcommittees and continued as tentative:

Tentative Specifications for Milled Toilet Soap (D 455 – 37 T), proposed by Section C, Subcommittee II,
Tentative Specifications for Soda Ash (D 458 – 37 T), proposed by Section F, Subcommittee II, and
Tentative Definitions of Terms Relating to Soaps and Detergents (D 459 – 37 T), proposed by Subcommittee III.

Adoption of Tentative Standards as Standard:

The committee recommends that the following two tentative specifications and methods of analysis be approved for reference to letter ballot of the Society for adoption as standard:

Tentative Specifications for Caustic Soda (D 456 – 37 T), proposed by Section F, Subcommittee II,
Tentative Specifications for Modified Soda (Sesquicarbonate Type) (D 457 – 37 T), proposed by Section F, Subcommittee II, and

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[1] See pp. 1202 to 1261.

Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460 – 37 T), proposed by Section A, Subcommittee I.[1]

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 59 members; 42 members returned their ballots, the results being as follows:

As a result of the election held at the March meeting, the following officers and members of the Advisory Committee were chosen to serve for the succeeding two-year period:

Chairman, H. P. Trevithick
Vice-Chairman, F. W. Smither
Secretary, B. S. Van Zile

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Specifications for White Floating Toilet Soap	41	0	1
Specifications for Chip Soap	40	1	1
Specifications for Powdered Laundry Soap	40	1	1
Specifications for Ordinary Laundry Bar Soap	41	0	1
Methods of Test for Particle Size of Soaps and Other Detergents	40	0	2
Methods for Determination of Combined Sodium and Potassium Oxides in Soaps	38	2	2
Chemical Analysis of Sulfonated (Sulfated) Oils	39	0	3
Chemical Analysis of Special Detergents	39	1	2
II. REVISIONS OF TENTATIVE STANDARDS			
Specifications for Milled Toilet Soap (D 455 – 37 T)	41	0	1
Specifications for Soda Ash (D 458 – 37 T)	42	0	0
Definitions of Terms Relating to Soaps and Detergents (D 459 – 37 T)	37	2	3
III. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Caustic Soda (D 456 – 37 T)	42	0	0
Specifications for Modified Soda (Sesquicarbonate Type) (D 457 – 37 T)	42	0	0
Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460 – 37 T)[a]	42	0	0

[a] This recommendation did not receive the approval of the Society and the methods are accordingly being continued as tentative.

In addition to the work completed this year, the committee is considering other definitions, specifications for soap powder and built soaps, trisodium phosphate and metasilicate, and new methods of analysis for some of these materials, as well as revision of certain other methods. It is also preparing to discuss methods of analysis for mixtures of alkali detergents, a test for detergency, and analytical methods for determining rosin, carbon dioxide, and water insoluble matter in soaps and soap products. Specifications for liquid soaps, as well as other industrial soaps, and low-grade soap powders are also being prepared. It is also hoped that results will be obtained on the specifications for some of the sulfonated and sulfated dry-cleaning and metal detergents, as well as on the methods of test for dry-cleaning and metal detergents.

Members of the Advisory Committee:

J. B. Crowe
J. E. Doherty
G. E. Hopkins
Frederick Krassner
W. G. Morse
M. L. Sheely

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Methods of Testing (J. B. Crowe, chairman):

Section A on Soaps (M. L. Sheely, chairman).—This section is recommending the adoption as standard of the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460 – 37 T).[1, 2] New Methods of Test for Particle Size of Soaps and Other Detergents and Methods for the Determination of Combined Sodium and Potassium Oxides in Soaps, Lindo-Gladding methods, are being proposed for publication as tentative as appended hereto.[3]

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[1] See Summary of Proceedings, p. 29.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1266 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1472.

[3] See pp. 1236 and 1234.

Section B on Sulfonated Detergents (Ralph Hart, chairman).—This section is recommending that the Proposed Methods of Chemical Analysis of Sulfonated (Sulfated) Oils,[1] which were published as information in the report of the committee last year, be accepted for publication as tentative.

Section D on Special Detergents (W. H. Koch, chairman).—The Proposed Methods of Chemical Analysis of Special Detergents,[2] published as information in the 1937 report of the committee, are being proposed for publication as tentative. The section is continuing work on these methods of analysis, having in mind including methods for routine testing and also more accurate methods for umpire work. Analytical procedures for determining water insoluble matter, total alkali and P_2O_5 in trisodium phosphate, as well as a more accurate gravimetric method for determination of CO_2 as sodium carbonate, will shortly be balloted on by the section.

Subcommittee II on Specifications (F. W. Smither, chairman):

This subcommittee held two meetings during the year. The various sections of Subcommittee II have been quite active in so far as the nature of their subjects would permit.

Section A on Textile Soaps (C. L. Nutting, chairman) is now in a position to proceed with its work, owing to the data supplied by Section C on Straight Soaps.

Section B on Built Soaps (Frederick Krassner, chairman) is submitting for publication as tentative, proposed Specifications for Ordinary Laundry Bar Soap, appended hereto.[3]

Section C on Straight Soaps (Israel Katz, chairman) is proposing for publication as tentative, three new Specifications for White Floating Toilet Soap, for Chip Soap, and for Powdered Laundry Soap, as appended hereto.[4]

Section C is also recommending that the Tentative Specifications for Milled Toilet Soap (D 455 - 37 T)[5] be revised as follows and continued as tentative:

Section 4.—Change Paragraph (*a*), the first sentence of Paragraph (*c*) and the formula to read as follows by the addition of the italicized figures and the omission of those in brackets:

> (*a*) The material shall be purchased by net weight provided the matter volatile at 105 C. is neither above nor below [15] *12* per cent.
>
> (*c*) On deliveries containing less than 15 per cent of matter volatile at 105 C. settlement shall be made on the basis of a product containing [15] *12* per cent moisture, that is, [0.85] *0.88* lb. of non-volatile matter shall be considered 1 lb. of soap.
>
> Net weight of material to be paid for on [15] *12* per cent moisture and volatile matter basis
>
> $$= \frac{\text{Net weight as received} \times (100 - \text{percentage of loss at 105 C.})}{[85]\ \mathit{88}}$$

The work of Section D on Dry Cleaning Detergents was retarded because of the resignation of its chairman. Mr. G. P. Fulton of the National Association of Dyers and Cleaners has taken over the chairmanship of this section.

In Section E on Sulfonated Detergents (J. B. Crowe, chairman) cooperative laboratory work is in progress on a method to evaluate sulfonated detergents by means of washing standard soiled cloth in a launderometer under varying conditions of temperature, solution concentration and alkalinity, and subsequently grading the wash towels by photometric readings.

Section F on Special Detergents (C. C. Zeigler, chairman) is working on specifications for trisodium phosphate which are to be submitted to letter ballot vote in the section. Specifications for metasilicate have not yet been completed but these may be available for the next meeting of the committee. Section F is recommending that the Tentative Specifications for Soda Ash (D 458 – 37 T)[1] be revised as follows and continued as tentative:

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[1] See p. 1238.

[2] See p. 1258.

[3] See p. 1204.

[4] See pp. 1202, 1210 and 1206.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1264 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1470.

Section 3.—Delete the requirement for sodium hydroxide which reads as follows:

Sodium hydroxide (NaOH), max., per cent.............................. 0.1

Section 5.—From the table on types of soda ash delete "(Type A)" after the word Light, and "(Type B)" after the word Extra-light.

Section F also recommends that the Tentative Specifications for Caustic Soda (D 456 – 37 T)[2] and for Modified Soda (Sesquicarbonate Type) (D 457 – 37 T)[2] be approved for reference to letter ballot of the Society for adoption as standard.

Section G on Metal Cleaners has been unable through various causes to produce any tangible results. However the section has been reorganized under the chairmanship of Mr. J. C. Harris and it is hoped that active work will be carried forward.

Subcommittee III on Nomenclature and Definitions (Frederick Kenney, chairman):

Subcommittee III is recommending the withdrawal of the definitions for soap, commercial soap, anhydrous real soap, powdered soap, soap content, soap powder, and alkali cleanser appearing in the Tentative Definitions of Terms Relating to Soaps and Detergents (D 459 – 37 T).[3] The definition of built soap in the Tentative Standard D 459 – 37 T is being retained and the Subcommittee is further recommending the addition of definitions for the following seventeen terms for publication as tentative, as appended hereto:[4]

Soap
Anhydrous soap
Soap content
Solid soap
Bulk soap
Bar soap
Cake soap
Paste soap
Flake soap
Chip soap
Bead soap
Granulated soap
Powdered soap
Liquid soap
Alkaline detergent
Builder
Detergent

This report has been submitted to letter ballot of the committee which consists of 59 members; 42 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. P. TREVITHICK,
Chairman.

B. S. VAN ZILE,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1262 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1468.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1260, 1261 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1466, 1467.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1289 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1495.

[4] See p. 1262.

REPORT OF COMMITTEE D-13
ON
TEXTILE MATERIALS

Committee D-13 on Textile Materials has held two meetings during the year, one on October 20 to 22, 1937, in New York City, and the other on March 9 to 11, 1938, in Washington, D. C. The number of members and guests registered was 117 and 101, respectively. The total number present at these two meetings set a new high record of attendance. A third meeting will be held in June at Atlantic City, N. J., in conjunction with the annual meeting of the Society.

The executive direction of the committee's activities has required four meetings of the officers and three meetings of the Advisory Committee. The committee's work on standardization has been carried on with seemingly undiminished vigor and interest by its 25 subcommittees. Of these, 18 held sessions at the fall meeting and 15 at the spring meeting. According to the official records in the 1937 Year Book, Committee D-13 has this year become the second largest standing committee in the Society.

A Symposium on Methods of Testing Textiles was a feature of the October meeting, and one on the Finishing of Fabrics was a high light of the March meeting. An excellent exhibit, showing interesting phases of the work of the committee, was on display at the latter meeting.

The Advisory Committee has approved the following changes in subcommittee organization and chairmanships: a new Section III on Rayon Staple and Spun Rayon Yarns, under Subcommittee A-2 on Rayon, has been formed, and K. B. Cook has been made its chairman; A. G. Scroggie was appointed to the chairmanship of Subcommittee B-2 on Nomenclature and Definitions, *vice* E. D. Fowle resigned, and G. H. Harnden was made chairman of Subcommittee A-3, Section II on Felt, *vice* J. F. Marshall resigned.

The Advisory Committee has also approved the following appointments of representatives of Committee D-13: A. G. Scroggie on Committee E-8 on Nomenclature and Definitions; R. H. Brown on the new Technical Committee X on Conditioning under Committee E-1 on Methods of Testing; W. H. Bassett, Jr., on the Sectional Committee on Electrical Insulating Materials (A. S. A. Project: C59) in place of F. S. Mapes who was serving in a temporary capacity; and J. A. Levering on the Standing Committee on Wool and Part-Wool Fabrics, Commercial Standard CS 65–38, in place of Werner von Bergen who resigned.

Two members of the committee have been elected to the Executive Committee of the Society, namely, Dean Harvey and G. E. Hopkins. H. J. Jaquith has been appointed to represent the Society on the Sectional Committee on Specifications and Standards for Sheets and Sheeting (A.S.A. Project, L-4) in place of A. M. Tenney, resigned. Mr. Jaquith has also been appointed to membership on the New York District Committee. H. J. Ball has been named by the Executive Committee to serve on Committee E-6 on Papers and Publications.

The growth in the membership of the committee, the additional branches of the textile field into which the committee's activities have naturally extended, and the marked increase in the volume of work turned out by the subcommittees, all of which have occurred within the past few years, have resulted in a proportionately expanded secretarial load. To provide more adequately for this, the committee voted approval of a plan proposed by the Advisory Committee levying an annual assessment of $5.00 on each member and charging a registration fee of $3.00 at each meeting for non-members and for those members who have not paid the assessment. This plan was put into effect January 1, 1938.

Two of the committee's standards, namely, the General Methods of Testing and Tolerances for Cotton Yarns and Threads (D 180 – 37) and the Methods of Testing and Tolerances for Tubular Sleeving and Braids (D 354 – 36) have been endorsed by the committee for submission to the American Standards Association for approval as American standards.

During this year a plan has been consummated whereby the American Standards Association has become the representative of American groups interested in standardization in the textile field, on the newly organized Committee No. 38 on Textiles of the International Standards Association. The plan also provides that all matters pertaining to the work of the I.S.A. committee are to be referred to Committee D-13, which, through its chairman, shall decide what member or members should be asked to consider the matters from the American viewpoint. This arrangement, sponsored by the American Society for Testing Materials, has been agreed to by the National Bureau of Standards, the Cotton Textile Institute, the National Association of Wool Manufacturers, the National Federation of Textiles, Inc., the Textile Foundation, and the United States Institute for Textile Research. Thus, Committee D-13 becomes an important link in the exchange of ideas on matters dealing with the international unification of textile standards.

The attention of Committee D-13 has been drawn to the need in the industry for test methods for the evaluation of the effect of finishing agents. G. E. Hopkins is conducting a preliminary survey to determine the extent of interest in this subject amongst producers and consumers of these materials, and to learn whether they are prepared to furnish adequate financial backing for an extensive investigation of the problems involved.

The Executive Committee has assigned to Committee D-13 jurisdiction over glass fiber and its products. Mr. Dean Harvey is making inquiry of the producers and consumers of this new fiber to ascertain their interest in the establishment of standards in this field. A meeting of those interested is to be held in conjunction with the annual meeting in June to discuss the problems involved and to determine whether the organization of a subcommittee is advisable.

The present membership of the committee is 190; of whom 82 are classified as producers, 47 as consumers, and 61 as general interest members.

Subsequent to the 1937 annual meeting, Committee D-13 presented to the Society on August 26, 1937, through Committee E-10 on Standards, new Tentative Specifications and Methods of Test for Fineness of Wool Tops (D 472 - 37 T). These specifications were accepted[1] by Committee E-10 for publication as tentative and appear in the 1937 *Proceedings*.[2]

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[1] In submitting this recommendation to Committee E-10 on Standards, Committee D-13 reported results of the letter ballot vote as follows: Of a total membership of 186, 106 members returned their ballots, of whom 42 voted affirmatively, 0 negatively, and 64 members marked their ballots "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1218 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1424.

RECOMMENDATIONS AFFECTING STANDARDS

The recommendations of the committee regarding the standards and tentative standards under its jurisdiction are summarized below, together with the analysis of the letter ballot on each item. Comments, where necessary, are made under the Activities of Subcommittees.

New Tentative Standards:

The committee presents for publication as tentative the following six new specifications and methods of test, appended hereto:[1]

Tentative Method of Test for Fastness of Colored Textile Fabrics to Light,
Tentative Methods of Testing and Tolerances for Spun Rayon Yarns and Threads,
Tentative Methods of Testing and Tolerances for Yarns Spun from Wool Mixed with Fibers Other Than Wool,
Tentative Specifications for Single-Ply Bleached Cotton Broadcloth,
Tentative Specifications for Bleached Wide Cotton Sheeting, and
Tentative Specifications for Terry (Turkish) Toweling.

Revisions of Tentative Standards:

The committee is presenting revisions in the following tentative definitions and two methods of test and recommends that, as revised, they be continued as tentative:

Tentative Definitions and Terms Relating to Textile Materials (D 123 – 37 T),[2] revised as appended hereto,[3]
Tentative Methods of Testing Pile Floor Covering (D 418 – 37 T),[2] revised as proposed in the Appendix, and
Tentative Methods of Test for Wool Felt (D 461 – 37 T),[2] revised as proposed in the Appendix.

Revisions of Standards:

The committee recommends for immediate adoption, revisions in the following four methods of test, and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that these modifications may be referred to letter ballot of the Society:

Standard General Methods of Testing Woven Textile Fabrics (D 39 – 36),[4] revised as proposed in the Appendix,
Standard Methods of Testing and Tolerances for Tire Cord, Woven and on Cones (D 179 – 33),[4] revised as appended hereto,[5]
Standard Methods of Testing and Tolerances for Woolen Yarns (D 403 – 36),[4] revised as proposed in the Appendix, and
Standard Methods of Testing and Tolerances for Worsted Yarns (D 404 – 36),[4] revised as proposed in the Appendix.

The committee recommends for publication as tentative, revisions of the following four standards:

Standard Specifications for Textile Testing Machines (D 76 – 37),[6] revised as appended hereto,[7]
Standard General Methods of Testing and Tolerances for Cotton Yarns and Threads (D 180 – 37),[8] revised as appended hereto,[7]
Standard Methods of Testing and Tolerances for Cotton Sewing Threads (D 204 – 36),[8] revised as appended hereto,[7] and
Standard Specifications and Methods of Test for Cotton Goods for Rubber and Pyroxylin Coating (D 334 – 34),[8] revised as appended hereto.[7]

The committee recommends that the following editorial change be made in the Standard Methods of Testing and Tolerances for Knit Goods (D 231 – 33):[8]

Section 14.—Change Paragraph (*a*) from its present form: namely,

14. (*a*) The strength shall be determined on either an approved type of pendulum machine or an approved type of diaphragm bursting tester.

to read as follows:

14. (*a*) The machines used for determining the bursting strength shall be either of the following types and shall conform to the requirements of the following sections of the Standard Specifications for Textile Testing

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[1] See pp. 1163, 1166, 1176, 1157, 1159, 1161.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1243, 1235, 1226 (1937); also Book of A.S.T.M. Tentative Standards, pp. 1449, 1441, 1432.

[3] See p. 1193.

[4] 1936 Book of A.S.T.M. Standards, Part II, pp. 1334, 1375, 1388, 1393.

[5] These methods were adopted as standard by the Society and appear in the 1938 Supplement to Book of A.S.T.M. Standards, p. 227.

[6] 1937 Supplement to Book of A.S.T.M. Standards, p. 241.

[7] See pp. 1333 and 1334.

[8] 1936 Book of A.S.T.M. Standards, Part II, pp. 1351, 1359, 1295, 1347.

Machines (A.S.T.M. Designation: D 76) of the American Society for Testing Materials: (1) an approved type of pendulum machine (Section 2) equipped with a burst attachment (Section 8); (2) an approved type of diaphragm bursting tester (Section 9).

Change Paragraph (*c*) to read as follows by the addition of the italicized word and the omission of the words in brackets:

> (*c*) At least 10 test pieces shall be cut, the smallest dimension of which shall be at least $\frac{1}{2}$ in. greater than the outside diameter of the ring-*clamp* mechanism [referred to in Section 14 (*a*)].

Adoption of Tentative Standard as Standard:

The committee recommends that the Tentative Method of Test for Strength of Rayon Woven Fabric when Wet (D 415 - 35 T),[1] be approved for submission to letter ballot of the Society for adoption as standard.

Withdrawal of Standard:

The committee recommends the withdrawal of the Standard Specifications for 23/5/3 Carded American Tire Cord (D 298 - 29).[2]

Tentative Standards and Revisions Continued as Tentative:

The committee recommends that all other tentative standards and tentative revisions of standards under its jurisdiction not specifically referred to under Activities of Subcommittees be continued as tentative for another year.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 190 members; 111 members have returned their ballots, with the results shown in the accompanying Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. NEW TENTATIVE STANDARDS			
Method of Test for Fastness of Colored Textile Fabrics to Light	63	2	46
Methods of Testing and Tolerances for Spun Rayon Yarns and Threads	64	0	47
Methods of Testing and Tolerances for Yarns Spun from Wool Mixed with Fibers Other than Wool	59	0	52
Specifications for Single-Ply Bleached Cotton Broadcloth	53	2	56
Specifications for Bleached Wide Cotton Sheeting	58	3	50
Specifications for Terry (Turkish) Toweling	46	3	62
II. REVISIONS OF TENTATIVE STANDARDS			
Definitions and Terms Relating to Textile Materials (D 123 - 37 T)	91	0	20
Methods of Testing Pile Floor Covering (D 418 - 37 T)	45	0	66
Methods of Test for Wool Felt (D 461 - 37 T)	47	0	64
III. REVISIONS OF STANDARDS			
General Methods of Testing Woven Textile Fabrics (D 39 - 36), immediate adoption	87	0	24
Methods of Testing and Tolerances for Tire Cord, Woven and on Cones (D 179 - 33), immediate adoption	54	0	57
Methods of Testing and Tolerances for Woolen Yarns (D 403 - 36), immediate adoption	55	0	56
Methods of Testing and Tolerances for Worsted Yarns (D 404 - 36), immediate adoption	55	0	56
Specifications for Textile Testing Machines (D 76 - 37)	83	1	27
General Methods of Testing and Tolerances for Cotton Yarns and Threads (D 180 - 37)	75	1	35
Methods of Testing and Tolerances for Cotton Sewing Threads (D 204 - 36)	64	0	47
Specifications and Methods of Test for Cotton Goods for Rubber and Pyroxylin Coating (D 334 - 34)	59	0	52
IV. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method of Test for Strength of Rayon Woven Fabric when Wet (D 415 - 35 T)	52	1	58
V. WITHDRAWAL OF STANDARD			
Specifications for 23/5/3 Carded American Tire Cord (D 298 - 29)	49	0	62

ACTIVITIES OF SUBCOMMITTEES

Subcommittee A-1 on Cotton and Its Products (K. B. Cook, chairman):

Section I on Cotton (R. W. Webb, chairman).—This section is continuing its work on methods for determining important fiber properties and its efforts to stimulate more interest in raw cotton.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 1250 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 1415.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1306.

In line with the educational program of the section, the following important papers were presented at the March, 1938, meeting based on research by the U. S. Department of Agriculture: "Some Breeding and Production Aspects of Cotton Quality," by Henry W. Barre; "Cross-Sectional and Related Structural Features of Cotton Fibers Influencing Quality," by Enoch Karrer; and "Some Possibilities and Limitations of X-ray Methods for Measuring the Strength of Raw Cotton," by Carl M. Conrad.

Section II on Cotton Yarns and Threads (A. C. Clifford, chairman).—This section is recommending a tentative revision in the Standard General Methods of Testing and Tolerances for Cotton Yarns and Threads (D 180 – 37) which includes a change in the standard regain for cotton yarns and threads, and provides "appearance" standards for cotton yarns. The revision is given in detail in the Appendix.[1]

The section is also recommending a tentative revision, as given in the Appendix,[1] in the Standard Methods of Testing and Tolerances for Cotton Sewing Threads (D 204 – 36) to provide a method for determining the yards of thread in a package.

The work by this section on the development of heavy-duty clamps for strength testing of heavily plied yarns has been completed and recommendations have been made to the Section on Testing Machines. Consideration is now being given to procedures for the determination of twist and for sample size to be included in the methods of testing cotton yarns and threads.

Section III on Light and Medium Cotton Woven Fabrics (R. T. Fisher, chairman).—This section is recommending a tentative revision, as given in the Appendix,[1] in the Standard Specifications and Methods of Test for Cotton Goods for Rubber and Pyroxylin Coating (D 334 – 34) to provide improved methods for the determination of sizing in cotton gray goods and to change the allowable percentage of starch in broken twills and sateens.

Section IV on Tire Fabrics (Martin Castricum, chairman).—This section is recommending for immediate adoption, a revision of the Standard Methods of Testing and Tolerances for Tire Cord, Woven and on Cones (D 179 – 33), as appended hereto.[2] No material modification in substance is involved other than the deletion of certain parts of the standard which have become obsolete, thus bringing the standard into conformity with current technical practice. It is also recommending the withdrawal of the Standard Specifications for 23/5/3 Carded American Tire Cord (D 298 – 29) which is now obsolete.

Work is now under way on an interlaboratory study of variations in physical characteristics of tire cord for the purpose of establishing requirements for sample size (number of tests) and degree of permissible variation for inclusion in Standard D 179. A large number of laboratories representing both producer and consumer members of the section are participating.

Section VI on Narrow Fabrics (F. S. Mapes, chairman).—This section is studying the methods of measuring thickness of tapes and tubular sleeving and braids, with particular reference to the type of measuring gage. It is also considering the preparation of specifications for ladder tapes for Venetian blinds pursuant to a request from a producer of these tapes.

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[1] See pp. 1333 and 1334.

[2] These methods were adopted as standard by the Society and appear in the 1938 Supplement to Book of A.S.T.M. Standards, p. 227.

Subcommittee A-2 on Rayon and Its Products (A. M. Tenney, chairman):

On the recommendation of this subcommittee, a new Section III on Rayon Staple and Spun Rayon Yarns was appointed by the Advisory Committee.

Section I on Rayon (A. M. Tenney, chairman).—This section is studying strength test methods, sampling, establishment of tolerances for fineness and number of filaments for rayon yarns, test methods and tolerances for luster characteristics, the establishment of the single-strand test as the preferred method, and the half-meter length for the single-strand test specimen.

Section II on Rayon Fabrics (Alexis Sommaripa, chairman).—This section is recommending the adoption as standard of the Tentative Method of Test for Strength of Rayon Woven Fabric when Wet (D 415 - 35 T), as this test method has proved to be satisfactory.

Methods developed for testing consumer fabrics against actual consumer wear are being studied by the section, and work on standards for minimum strengths of cloths used for different types of wearing apparel is being undertaken.

Section III on Rayon Staple and Spun Rayon Yarns (K. B. Cook, chairman).—This section is presenting for publication new Tentative Methods of Testing and Tolerances for Spun Rayon Yarns and Threads, as appended hereto.[1] The extensive use of these yarns and general demand from the industry makes it imperative that standard methods of test be established. The section is now working on methods of test and tolerances for rayon staple.

Subcommittee A-3 on Wool and Its Products (G. E. Hopkins, chairman):

Section I on Wool (Werner von Bergen, chairman).—This section is working on a method for the determination of fiber length of wool[2] and on a laboratory method for the determination of shrinkage of grease wool. An interlaboratory investigation of the physical characteristics of mohair is in progress with a view to establishing methods for the identification of this fiber. Work on the standardization and classification of wool qualities is being continued.

Section II on Felt (G. H. Harnden, chairman).—This section is presenting a revision, as given in the Appendix, of the Tentative Methods of Test for Wool Felt (D 461 - 37 T). The revision adds a method for the determination of thickness of cut parts having a minimum linear dimension of 1 in. or less. The section is continuing its critical study of these methods and is planning a comprehensive program of work which includes the formulation of definitions and the development of methods of test for permanent set, permanent recovery, dimensions of cut parts other than thickness, diameter of felt wicks, swell in cut parts and in flat sheet and roll felt, and materials soluble in water and in hydrochloric acid.

Section III on Woolen and Worsted Yarns (Fred Noechel, chairman).—This section is presenting for publication new Tentative Methods of Testing and Tolerances for Yarns Spun from Wool Mixed with Fibers Other than Wool, as appended hereto.[3] The extensive use of yarns made from a mixture of wool and other fibers necessitated the development of specific methods of test.

The section is also presenting for immediate adoption, revisions, as given in the Appendix, of the Standard Methods of Testing and Tolerances for Woolen Yarns (D 403 - 36) and for Worsted Yarns (D 404 - 36). These revisions are for the purpose of clarifying the determination of oven-dry weight.

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[1] See p. 1166.

[2] See Editorial Note, p. 464.

[3] See p. 1176.

The section is continuing its study of test methods for woolen and worsted yarns and yarns made with wool mixed with other fibers.

Section IV on Pile Floor Coverings (A. G. Ashcroft, chairman).—This section is presenting a revision, as given in the Appendix, of the Tentative Methods of Testing Pile Floor Covering (D 418 – 37 T) which adds a statement as to the precision of the method for the determination of back thickness when the specified number of tests are made. This is the first appearance of a statement of the precision of a method in the standards of Committee D-13.

The section is continuing its work on the development of wear test methods and their correlation with actual service tests, chemical tests for spotting, crocking and bleeding, method of measurement for tuft length, and statistical studies to establish the proper sample size for the measurement of the various characteristics with the desired precision.

Section V on Woolen and Worsted Fabrics (F. A. Prisley, chairman).—This section is reviewing the Tentative Methods of Testing and Tolerances for Certain Wool and Part Wool Fabrics (D 462 – 37 T) which were issued last year, and is planning the development of additional physical and chemical tests on fabrics.

Subcommittee A-4 on Asbestos and Its Textile Products (F. S. Mapes, chairman):

This subcommittee is reviewing the present standards under its jurisdiction with a view to clarifying the methods for the determination of the cut of the various types of asbestos roving and yarns; different types of gages for measuring thickness of tapes are being studied; methods of testing and tolerances for asbestos cloth are being developed. The Standard Specifications and Methods of Test for Asbestos Tape for Electrical Purposes (D 315 – 37) will be revised to include the properties of 0.010-in. tape.

Subcommittee A-5 on Bast and Leaf Fibers and Their Products (A. R. Howe, chairman):

This subcommittee is actively engaged in drafting methods of testing and tolerances for jute yarns, twines and rovings, with interlaboratory tests on the characteristics involved.

Subcommittee A-6 on Household and Garment Fabrics (Ruth O'Brien, chairman):

This subcommittee is presenting for publication three new tentative specifications covering respectively: Bleached Wide Cotton Sheeting, Terry (Turkish) Toweling, and Single-Ply Bleached Cotton Broadcloth, as appended hereto.[1] These specifications and test methods are based on extensive analyses and comparisons made by the Bureau of Home Economics of the U. S. Department of Agriculture, and in collaboration with the members of the subcommittee. The proposals for sheetings are in essential agreement with the specifications recommended by the Subcommittee on Sheets of the Advisory Committee on Ultimate Consumer Goods, functioning under the American Standards Association. They may be considered as representative of the various grades of the fabrics covered.

The subcommittee is extending its work on broadcloths to include plied fabrics and is undertaking cooperative projects on upholstery materials, mercerization, and water absorption of toweling.

Subcommittee B-1 on Methods and Machines (W. D. Appel, chairman):

This subcommittee sponsored a Symposium on Testing Methods at the October, 1937, meeting. The titles of the symposium papers are given under the activities of Subcommittee B-6.

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[1] See pp. 1157 to 1162.

Section I on Methods (W. D. Appel, chairman).—This section is recommending for immediate adoption a revision of the Standard General Methods of Testing Woven Textile Fabrics (D 39 – 36). This revision, which is given in the Appendix, changes the tolerances for the standard temperature to the present generally accepted values. The section is also presenting for publication as information a Proposed Method for the Quantitative Determination of Tussah Silk in Mixtures with Other Fibers.[1]

The section is working on the development of methods for the quantitative determination of lanital in mixtures and on an accelerated aging test for silk.[1] Methods for the determination of tearing strength are being investigated with particular reference to the use of multiple test specimens. An important matter before the section is the development of requirements for sample size (number of tests) applicable to the methods of test set forth in the Standard General Methods of Testing Woven Textile Fabrics (D 39 – 36).

Section II on Machines (H. J. Ball, chairman).—This section is recommending for publication as tentative, revisions of the Standard Specifications for Textile Testing Machines (D 76 – 37), as appended hereto,[2] which clarify the method of calibration of Type A machines and add requirements for diaphragm bursting testers.

The section is studying the relation between the rate of loading with Type B machines and the strength and elongation of cotton yarns, and is collecting data on which to base specifications for sensitivity of Type A machines. At the March, 1938, meeting a paper was presented by I. J. Saxl on the subject of the Determination of the Dynamic Characteristics of Individual Filaments and was accompanied by a demonstration of a machine developed for this purpose.

Section III on Atmospheric Conditions (R. H. Brown, chairman).—This section concerns itself mainly with problems involved in the conditions under which tests are made, for the guidance of the other subcommittees. In line with this function, it recommends that the temperature of the standard atmosphere be 70 F. with a permissible variation of plus or minus 2 F. It also recommends that standard conditions be specified in all test procedures affected by atmospheric conditions.

The section is working on the following important problems: defining the temperature and humidity tolerances of the standard conditions with reference to the extent, duration, and frequency of variations in the test room; methods of conditioning test specimens with respect to method of exposure, time to reach equilibrium, and effects of air motion and previous treatment of the sample; and the effect of barometric pressure on the accuracy of psychrometric humidity observations and regain.

The section is planning a full display and demonstration of different methods and instruments for measuring and recording humidity, temperature, and regain, accompanied by a paper on laboratory conditioning methods and types of control equipment.

Subcommittee B-2 on Nomenclature and Definitions (A. G. Scroggie, chairman):

This subcommittee is presenting an extensive revision of the Tentative Definitions and Terms Relating to Textile Materials (D 123 – 37 T), as appended hereto.[3] This revision is the first step in the division of definitions and terms into two groups, those to be retained in Tentative Definitions D 123, and those to be grouped in a glossary to be published as an appendix to the compilation of "A.S.T.M. Standards on Textile Materials." The subcommittee plans to continue its study of the present definitions with a view to their improvement and to add such new terms as seem necessary.

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[1] These proposed methods were published as information and appear in Appendices VI, VII and VIII, respectively, of the volume, "A.S.T.M. Standards on Textile Materials," pp. 269 to 271, October, 1938; available as a separate publication.

[2] See p. 1333.

[3] See p. 1193.

Subcommittee B-4 on Bleaching, Dyeing and Finishing (W. M. Scott, chairman):

This subcommittee is presenting for publication a new Tentative Method of Test for Fastness of Colored Textile Fabrics to Light, as appended hereto,[1] which fills the need for a standardized procedure for testing light fastness. This method is based on a method developed by the American Association of Textile Chemists and Colorists.

The subcommittee is conducting a cooperative study of the various types of tests for water resistance of textiles. Other projects before the subcommittee are: methods of test for acidity, alkalinity, fire-resistance, and mildew-resistance of textiles, and a standard method for measuring fluidity of cuprammonium solutions of cotton or rayon cellulose.

This subcommittee sponsored a Symposium on Finishing at the March, 1938, meeting. The titles of the symposium papers are given under the activities of Subcommittee B-6.

Subcommittee B-5 on Sampling, Presentation and Interpretation of Data (A. G. Ashcroft, chairman):

This subcommittee is advising with Subcommittee A-1, Section IV on Tire Fabrics, with Subcommittee A-3, Section IV on Pile Floor Coverings, and with Subcommittee A-5 on Bast and Leaf Fibers and Their Products, in the solution of their specific problems on the determination of suitable sample size. It is also collaborating with Subcommittee B-1, Section I on Methods, in the development of a technique suitable for general use for the same purpose. This will contain specific directions for procedure and be based on approved statistical principles.

Subcommittee B-6 on Papers (Dean Harvey, chairman):

This subcommittee arranged for a Symposium on Testing Methods at the October, 1937, meeting and a Symposium on Finishing at the March, 1938, meeting. The following papers were presented:

Symposium on Testing Methods:
"Tests for the Physical Properties of Fibers," by C. J. Huber,
"Tests for the Physical Properties of Yarns," by H. F. Schiefer,
"Tests for the Physical Properties of Textile Fabrics," by Ethel L. Phelps,
"Abrasion and Wear Testing Machines for Textiles," by H. J. Ball, and
"Microscopic Test Methods," by E. R. Schwarz.

Symposium on Finishing:
"Permanent Finishes on Textiles from the Viewpoint of the Manufacturer," by K. H. Barnard,
"Permanent Finishes on Textiles from the Viewpoint of the Consumer," by Ephraim Freedman,
"Specifications of Uniform Color Tolerances for Textiles," by D. B. Judd,
"Consumer Testing of Finished Textiles," by Nannene Gowdy, and
"Standardization of a Method for Measuring the Fluidity of Dispersions of Cellulose in Cuprammonium Solutions," by R. T. Mease.

Arrangements were also made for the presentation of the Farm Credit Administration's motion picture "The Marketing of Wool."

Abstracts of the above papers are being prepared for publication in the 1938 edition of the compilation of "A.S.T.M. Standards on Textile Materials." The subcommittee is planning a Symposium on Spun Rayon and Blended Fibers for the October, 1938, meeting.

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[1] See p. 1163.

The following officers were elected at the March, 1938, meeting for the two-year period from June, 1938, to June, 1940:

Chairman, H. J. Ball.
First Vice-Chairman, R. H. Brown.
Second Vice-Chairman, F. S. Mapes.
Secretary, W. H. Whitcomb.

This report has been submitted to letter ballot of the committee, which consists of 190 members; 111 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. J. BALL,
Chairman.

W. H. WHITCOMB,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting, Committee D-13 on Textile Materials presented to the Society on August 25, 1938, through Committee E-10 on Standards a proposed Tentative Method of Test for Fiber Length of Wool. This method was accepted by Committee E-10 and appears on p. 1173.

APPENDIX

PROPOSED REVISIONS IN STANDARDS FOR TEXTILE MATERIALS

In this Appendix are given proposed revisions in certain standards and tentative standards covering textile materials which are referred to earlier in this report. In connection with each title is given the reference to the publication in which the standard appears in its present form.

Revisions of Tentative Standards

Tentative Methods of Testing Pile Floor Covering (D 418 - 37 T):[1]

Section 9.—Designate this section as Paragraph (*a*) and add the following as a new Paragraph (*b*):

> (*b*) *Precision of Test Method.*—Approximately 9 times in 10 a determination of back thickness made in accordance with Paragraph (*a*) would be expected to differ not more than 4 per cent over or under the true average thickness as obtained by a large number of repeat measurements by each of four or more participating independent laboratories.

Tentative Methods of Test for Wool Felt (D 461 - 37 T):[1]

Section 6.—Add as a new Paragraph (*f*) the following method for determining the thickness of cut parts having a minimum linear dimension of 1 in. or less:

> (*f*) The thickness of cut parts having a minimum linear dimension of 1 in. or less shall be measured by the dial micrometer as prescribed in Paragraphs (*a*) to (*d*) by cutting to fit and closely nesting together a sufficient number of pieces to give a minimum linear dimension of $1\frac{1}{8}$ in. The parts shall not be nested so tightly that they bulge at the cut edges, since this will result in the obtaining of an erroneous reading.

Revisions of Standards, Immediate Adoption

Standard General Methods of Testing Woven Textile Fabrics (D 39 - 36):[2]

Section 2 (*b*).—Change the last sentence of this section to read as follows by the addition of the italicized words and the omission of the words, symbols, and figures in brackets:

> A tolerance of [±] *plus or minus* 2 per cent is permitted in relative humidity and [plus 10 F. (6 C.)] *plus or minus 2 F.* (*1.1 C.*) in temperature.

Standard Methods of Testing and Tolerances for Woolen Yarns (D 403 - 36):[2]

Section 4.—Delete this section on "Rejection" which reads as follows, renumbering the subsequent sections accordingly:

> 4. Yarn may be rejected if it fails to meet any of the requirements specified. In case of rejection, the vendor must be notified within 10 days of the shipment.

New Section.—Under methods of testing add the following as a new Section 7:

> 7. *Test Condition.*—All yarns shall be tested under standard condition in accordance with Section 4 (*d*).

Section 14.—Change this section on regain determination from its present form: namely,

> 14. (*a*) Three samples of not less than 200 g. each shall be selected and weighed at the same time and under the same conditions as the bulk of the yarn which the samples represent. These samples shall then be placed in a conditioning oven at a temperature of 220 to 230 F. (105 to 110 C.). When no change in weight is noted in three consecutive weighings

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1235, 1226 (1937); also 1937 Book of A.S.T.M. Tentative Standards, pp. 1441, 1432.

[2] 1936 Book of A.S.T.M. Standards, Part II, pp. 1334, 1388.

at 10-min. intervals, the yarn shall be considered "oven dry."

(*b*) The difference between the average of the original (initial) weights of the sample and the average of the oven-dry weights of the same shall be considered as the "moisture loss."

(*c*) The percentage regain equals the moisture loss multiplied by 100 and divided by the average oven-dry weight.

to read as follows:

14. (*a*) Three samples of not less than 200 g. each shall be so selected that they represent the bulk of the shipment. These samples shall be weighed at the same time and under the same conditions as the bulk of the yarn. The samples shall then be placed in a conditioning oven at a temperature of 220 to 230 F. (105 to 110 C.). When, in three consecutive weighings at 10-min. intervals, the change in weight is not more than 0.10 per cent, the yarn shall be considered "oven dry." The final weight is the oven-dry weight.

(*b*) The difference between the original (initial) weight and the oven-dry weight of each of the three samples shall be calculated and the average of these results considered as the "moisture loss."

(*c*) The percentage moisture regain equals the moisture loss multiplied by 100 and divided by the average oven-dry weight.

Standard Methods of Testing and Tolerances for Worsted Yarns (D 404 - 36):[1]

In this standard make the same changes in Sections 4 and 14, and the addition of a new section on test conditions as recommended above for Standard Methods D 403 – 36.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1393.

REPORT OF COMMITTEE D-17
ON
NAVAL STORES

A meeting of Committee D-17 on Naval Stores was held in Rochester, N. Y., on March 9, 1938, during the group meetings of A.S.T.M. committees.

Consideration has been given by the committee to suggested changes in the procedure for the determination of the softening point of rosin by the Tentative Method of Test for Softening Point by Ring and Ball Apparatus (E 28 - 36 T). Arrangements have been made to compare results obtained with the tapered ring and the shouldered ring, particularly with the higher softening point rosins. Final decision on making use of the ball guide optional, the use of a hot plate, and the addition of a general provision regarding controlling the heating of the sample during preparation will be withheld until receipt of the detailed recommendations from Committee E-1.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standard:

The committee recommends that the new Tentative Methods of Sampling and Grading Rosin be accepted for publication as tentative, as appended hereto.[1] These methods are being prepared to make available in greater detail than now provided by the Regulations of the Naval Stores Act, the methods of sampling and grading, and tolerances permitted.

This recommendation has been submitted to letter ballot of the committee which consists of 19 members; 19 members returned their ballots all of whom have voted affirmatively.

Editorial Change in Standard Method:

The committee recommends the following minor editorial change in the Standard Method of Test for Determination of Toluol Insoluble Matter in Rosin (D 269 - 30):[2]

Section 2.—Change the second, third, and fourth sentences of this section to read as follows by the addition of the italicized word and figures and the omission of the words in brackets:

> When solution is apparently complete (no particles of rosin visible) filter at once through a 25-cc. porcelain Gooch crucible which has been previously prepared with a mat of pure well-washed asbestos (such as is used for the determination of barium sulfate) and which has been finally washed thoroughly with the solvent used, dry [in a boiling-water oven] *at 105 to 110 C.* for 30 min., cool in a desiccator, and weigh. If the rosin filtrate is not clear return it through the Gooch crucible until clear, finally washing the residue and the outside of the crucible free from rosin with additional hot solvent. Dry the crucible and contents to constant weight at 105 to 110 C. [in a boiling-water oven] (one hour usually suffices), cool in a desiccator, weigh, and calculate the percentage of toluol insoluble.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Softening Point of Rosin (C. E. Kinney, chairman).—Arrangements have been made to provide members with directions for making a shouldered ring and with samples with which to make comparisons of the results from both types of rings on regular and high softening point rosins.

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[1] See p. 832.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 759.

Subcommittee II on Crystallization (E. V. Romaine, chairman).—Considerable work has been done on crystallization, the investigation being for the purpose of developing a practical method of determining the crystallizing tendency of rosins. Two methods are being studied. In one, the rosin is made up into a concentrated solution using acetone as a solvent. In the other, the rosin is brought to and held in a molten condition in an air or electric oven. The length of time which elapses before crystals form in the solution or melt is noted. Both gum and wood rosin have been tested. It is planned to further study the methods with particular reference to gum rosin, and to varying the procedure in order that the time required may be reduced.

Subcommittee IV on Acid and Saponification Numbers and Unsaponifiable Matter (C. C. Zeigler, chairman).—This subcommittee has been requested to expand its work to include study of a method for the determination of petroleum ether insoluble matter and the determination of ash in rosin. Samples for test will be sent out by the chairman to members of the subcommittee.

Further work has been done on a study of the Tentative Methods of Test for Saponification Number of Rosin (D 464 – 37 T), and for Acid Number of Rosin (D 465 – 37 T). Some results have also been obtained on the development of a method for the determination of unsaponifiable matter and determination of petroleum ether insoluble matter, and the possible effect on results of exposure of the samples. Publication of final results will await completion of the work by members of the subcommittee.

With a view to carrying on a further collaborative study of the methods, the subcommittee has recommended that Methods D 464 – 37 T and D 465 – 37 T be continued as tentative.

The election of officers for the ensuing term of two years resulted in the reelection of the present incumbents.

This report has been submitted to letter ballot of the committee, which consists of 19 members; 18 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

F. P. VEITCH,
Chairman.

C. F. SPEH,
Secretary.

REPORT OF COMMITTEE D-18

ON

SOILS FOR ENGINEERING PURPOSES

Committee D-18 on Soils for Engineering Purposes was organized at a meeting in Washington, D. C., on November 16, 1936. Work in this field had been initiated under Committee D-4 on Road and Paving Materials but in view of the increasing interest in this subject it was considered desirable to organize a separate standing committee. Three further meetings of the committee have also been held: one in Chicago, Ill., on March 4, 1937, another in New York City on June 2, 1937, and the third in Rochester, N. Y. on March 10, 1938.

The purpose and the scope of work of the committee as defined in its regulations are as follows:

> *Scope.*—It will come within the jurisdiction of Committee D-18 to establish methods of sampling and methods of testing soils for engineering purposes, to consider the use of test results in specifications, to select acceptable nomenclature and definitions, and to promote research activity in the general field of properties and behavior of soils for engineering purposes.
>
> It will be the policy of this committee to avoid, in so far as it is possible, control over methods of design of engineering structures and all those features of general practice in the use of soil as an engineering material which may not compromise methods of sampling and testing. It will, however, be considered within the scope of the committee's work to promote by every desirable means the close cooperation of other organizations and committees whose field of endeavor is closely allied to that of soil testing.

Eleven subcommittees have been organized to carry out this program:

I on Nomenclature and Definitions (W. P. Kimball, chairman),
II on Classification of Soils (E. F. Preece, chairman),
III on Methods of Sampling Soils (R. R. Liteheiser, chairman),
IV on Method of Testing the Physical Characteristics of Soils (C. A. Hogentogler, chairman),
V on Methods of Testing for Stabilized Soils (F. C. Lang, chairman),
VI on Method of Testing for Compressibility and Elasticity of Soils (D. M. Burmister, chairman),
VII on Methods of Testing for Shearing Resistance of Soils (F. J. Converse, chairman),
VIII on Method of Testing for Mechanical Stability of Soils (W. R. Nelson, chairman),
IX on Methods of Testing for Bearing Capacity of Soils in Place (Load Tests) (W. S. Housel, chairman),
X on Method of Testing for Bearing Capacity of Piles (Load Tests) (A. E. Cummings, chairman), and
XI on Methods of Testing Drainage Properties of Soils (Capillarity and Permeability) (W. J. Schlick, chairman).

All subcommittees have made progress in the tasks assigned them and Subcommittee V, in particular, is approaching the stage where tentative standards may be prepared.

The nine existing A.S.T.M. methods of testing soils, originally prepared by the former Subcommittee D-5 on Soils for Highway Construction of Committee D-4 on Road and Paving Materials, have been assigned by the Executive Committee of the Society to Committee D-18. These tests have been studied by Subcommitttee IV on Methods of Testing the Physical Characteristics of Soils and, as a result, revisions are being presented in seven of the nine methods as indicated later in this report.

Two papers have been prepared by members of the committee for presentation to the Society at the annual meeting: one by E. E. Bauer, Assistant Professor of Civil Engineering, University of Illinois, on "A Study of Deflocculating

Agents Used in the Particle Size Determination of Soils,"[1] and the other by C. A. Hogentogler, Sr., Senior Highway Engineer, and Harold Allen, Materials Engineer, both of the U. S. Bureau of Public Roads, on "The Application of Soil Mechanics."[2]

The present membership of the committee now totals 67, of whom 18 are classified as producers, 25 as consumers, and 24 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

Revisions of Tentative Standards:

The committee recommends revisions of seven tentative methods of test, as follows:

Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (D 421 – 35 T):[3]

Section 3.—Change the first sentence of this section to read as follows by the addition of the italicized words:

> The soil sample as received from the field shall be dried thoroughly in the air *and the aggregations shall then be thoroughly broken up in the mortar with a rubber-covered pestle.*

Omit Paragraph (*c*) of this section which reads as follows:

> (*c*) *Tests of Binder Materials.*—Physical tests of binder material shall be performed only when it is desired to investigate the properties of the active constituents in sand-clay and gravel road-surfacing materials. In this case 100 g. of the material passing the No. 200 sieve are required and the tests shall be performed in the following order:
>
> Field moisture equivalent
> Plastic limit
> Liquid limit
> Volumetric shrinkage
> Centrifuge moisture equivalent.
>
> The material remaining after the conclusion of each test shall be used in the next test, except that the test for the centrifuge moisture equivalent shall be made with material not used in previous tests.

Tentative Method of Mechanical Analysis of Soils (D 422 – 35 T):[4]

Section 2 (*a*).—Change this section to read as follows by the addition of the italicized word and figure and the omission of those in brackets:

> (*a*) Balance.—[An analytical] *A* balance sensitive to [0.001] *0.1* g.

Figure 5.—Change this figure by the omission of the spring clips and clip blocks, and by replacing the wood base with a brass plate.

Section 4.—Change the first sentence of this section to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

> A [15] *10*-g. portion of the sample selected for mechanical analysis shall be used for the determination of the hygroscopic moisture.

Section 5.—Change the italic heading of Method A from its present form: namely,

> Method A: For Soils Having a Plasticity Index Less Than 20.

to read as follows:

> Method A: For Soils Having a Plasticity Index of 20 or Less.

Section 10 (*c*).—Change the description of *W* in the legend following the formula in this section from its present form: namely,

W = the weight of soil originally dispersed, in grams.

to read as follows:

W = the weight in grams, of soil originally dispersed minus the hygroscopic moisture.

Tentative Method of Test for Liquid Limit of Soils (D 423 – 35 T):[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 575 (1938).

[2] Published in ASTM BULLETIN, No. 94, October, 1938, p. 15.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, pp. 950 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 882.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, pp. 953 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 885.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 966 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 898.

Section 2.—Change Paragraph (*e*) of this section from its present form: namely,

(*e*) *Watch Glasses.*—Matched watch glasses which are held together by a suitable clamp and fit sufficiently tight to prevent loss of moisture during weighing.

to read as follows:

(*e*) *Containers.*—Suitable containers such as matched watch glasses which will prevent loss of moisture during weighing.

Change Paragraph (*f*) of this section by the addition of the italicized word and figure and the omission of those in brackets:

(*f*) Balance.—[An analytical] *A* balance sensitive to [0.001] *0.1* g.

Section 4.—Change the first sentence of Paragraph (*a*) of this section to read as follows by the addition of the italicized words and the omission of the word in brackets:

The air-dried soil shall be placed in the evaporating dish and thoroughly mixed with distilled water until the mass becomes [pasty] *a thick paste.*

Change the first sentence of Paragraph (*b*) of this section to read as follows by the addition of the italicized word and the omission of the word in brackets:

The dish shall be held firmly in one hand, with the groove parallel to the line of sight, and tapped lightly with a horizontal motion against the [palm] *heel* of the other hand ten times.

Change Paragraph (*e*) of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

(*e*) A small quantity of soil from that portion of the soil cake which was flowed shall be removed and placed in a pair of watch glasses *or other suitable containers.* The [watch glasses] *container* and soil shall then be weighed and the weight recorded. The soil in the [glasses] *container* shall be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the loss in weight due to drying shall be recorded as the weight of water.

Section 7.—Change the last two sentences of Paragraph (*a*) of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

This sample shall be placed in the evaporating dish and thoroughly mixed with a measured quantity of distilled water to a [pasty] ***putty-like*** consistency. A portion of this [paste] ***sample*** shall then be placed in the brass cup in the position shown in Fig. 1, leveled off to a depth of 1 cm., and divided by means of the grooving tool along the diameter through the centerline of the cam follower.

Change Paragraph (*c*) of this section from its present form: namely,

(*c*) The forgoing operations shall be repeated with samples of the soil at two or more additional moisture contents both above and below that requiring about 25 blows for closure of the groove.

to read as follows:

(*c*) The foregoing operations shall be repeated for two additional portions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that the number of shocks required to close the groove will be below and above 25.

Tentative Method of Test for Plastic Limit and Plasticity Index of Soils (D 424 – 35 T):[1]

Section 2.—Change Paragraph (*c*) of this section by the addition of the italicized words and the omission of the word in brackets:

(*c*) Surface for Rolling.—A ***ground***-glass plate or piece of [glazed] ***rough-textured*** paper on which to roll the sample.

Change Paragraph (*d*) of this section from its present form: namely,

(*d*) *Watch Glasses.*—Matched watch glasses which are held together by a suitable clamp and fit sufficiently tight to prevent loss of moisture.

to read as follows:

(*d*) *Containers.*—Suitable containers such as matched watch glasses which will prevent loss of moisture during weighing.

Change Paragraph (*e*) of this section to read as follows by the addition of the italicized word and figure and the omission of those in brackets:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part I, p. 970 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 902.

(*e*) Balance.—[An analytical] *A* balance sensitive to [0.001] *0.1* g.

Section 4.—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

4. The air-dried soil shall be placed in the evaporating dish and mixed with distilled water until the mass becomes plastic enough to be easily shaped into a ball. The ball of soil shall then be rolled between the palm of the hand and the ***ground***-glass plate or piece of [glazed] ***rough-textured*** paper with just sufficient pressure to form the soil mass into a thread (Fig. 1 (*a*)). When the diameter of the resulting thread becomes $\frac{1}{8}$ in. the soil shall be kneaded together and again rolled out. This process shall be continued until the crumbling of the soil (as shown in Fig. 1 (*b*)) prevents the formation of the thread. The portions of the crumbled soil shall then be gathered together and placed in watch glasses ***or other suitable containers.*** The [watch glasses] ***container*** and soil shall be weighed and the weight recorded. The soil in the [glasses] ***container*** shall then be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the loss in weight shall be recorded as the weight of water.

Tentative Method of Test for Centrifuge Moisture Equivalent of Soils (D 425 - 35 T):[1]

Section 2 (e).—Change this section to read as follows by the addition of the italicized word and figure and the omission of those in brackets:

(*e*) Balance.—[An analytical] *A* balance sensitive to [0.001] *0.1* g.

Tentative Method of Test for Field Moisture Equivalent of Soils (D 426 - 35 T):[2]

Section 2.—Change Paragraph (*d*) of this section from its present form: namely,

(*d*) *Watch Glasses.*—Matched watch glasses, held together by a suitable clamp and fitting sufficiently tight to prevent loss of moisture during weighing.

to read as follows:

(*d*) ***Containers.***—Suitable containers such as matched watch glasses which will prevent loss of moisture during weighing.

Change Paragraph (*e*) of this section to read as follows by the addition of the italicized word and figure and the omission of those in brackets:

(*e*) Balance.—[An analytical] *A* balance sensitive to [0.001] *0.1* g.

Section 4.—Change the fourth, fifth and sixth sentences of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

If the ***drop of*** water disappears in 30 sec. [a few more drops] ***a small increment*** of water ***(a few drops)*** shall be [added] ***mixed with the sample,*** and the procedure [shall be] repeated until the ***drop of*** water does not disappear in 30 sec. but spreads over the smoothed surface [and leaves] ***leaving*** a shiny appearance. A small portion of the soil on which the last drop of water was placed shall then be removed and placed between two watch glasses ***or other suitable containers.*** The weight of the [watch glasses] ***container*** and wet soil shall be determined and recorded.

Tentative Method of Test for Shrinkage Factors of Soils (D 427 - 35 T):[2]

Section 2.—Change Paragraph (*c*) of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

(*c*) [Porcelain Dish] *Shrinkage Dish.*—A circular porcelain ***or monel metal*** milk dish having a flat bottom and being about $1\frac{3}{4}$ in. in diameter [by] ***and*** about $\frac{1}{2}$ in. in height.

Change Paragraph (*h*) of this section to read as follows by the addition of the italicized word and figure and the omission of those in brackets:

(*h*) Balance.—[An analytical] *A* balance sensitive to [0.001] *0.1* g.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of

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[1] ***Proceedings,*** **Am. Soc. Testing Mats., Vol. 35, Part I, p. 973 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 905.**

[2] ***Proceedings,*** **Am. Soc. Testing Mats., Vol. 35, Part I, p. 976, 978 (1935); also 1937 Book of A.S.T.M. Tentative Standards, p. 908, 910.**

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
REVISIONS OF TENTATIVE STANDARDS			
Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (D 421 - 35 T)	43	1	5
Method of Mechanical Analysis of Soils (D 422 - 35 T)	42	2	5
Test for Liquid Limit of Soils (D 423 - 35 T)	40	4	5
Test for Plastic Limit and Plasticity Index of Soils (D 424 - 35 T)	43	1	5
Test for Centrifuge Moisture Equivalent of Soils (D 425 - 35 T)	43	1	5
Test for Field Moisture Equivalent of Soils (D 426 - 35 T)	43	1	5
Test for Shrinkage Factors of Soil (D 427 - 35 T)	42	2	5

72 members, 49 returned their ballots, the results being shown in Table I.

The election of officers for the ensuing term of two years resulted in the reelection of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 72 members, 49 members returned their ballots, of whom 40 have voted affirmatively and 4 negatively.

Respectfully submitted on behalf of the committee,

H. F. CLEMMER,
Chairman.

W. R. NELSON,
Secretary.

REPORT OF COMMITTEE D-19
ON
WATER FOR INDUSTRIAL USES

A meeting of Committee D-19 on Water for Industrial Uses was held on June 30, 1937, in New York City during the annual meeting of the Society. The committee sponsored a session on water at the 1937 annual meeting at which a group of five informative papers were presented and discussed. In addition, Committee D-19 held a Round-Table Discussion on Interpretations of Water Analyses from Analytical Data.

Subcommittee I on Policy and Procedure (F. N. Speller, chairman) has been discontinued and its functions have been assumed by the Advisory Committee, which consists of the officers of the main committee and the chairmen of the subcommittees. Subcommittee II, Editorial, has had its scope more clearly defined. M. A. Krimmel of the Hammermill Paper Co. has assumed the chairmanship of Subcommittee III on Methods of Sampling, succeeding R. E. Hall, resigned. A new subcommittee, designated Subcommittee V on Classification, has been formed and R. C. Adams of the U. S. Naval Engineering Experiment Station, Annapolis, has been appointed chairman.

RECOMMENDATIONS AFFECTING STANDARDS

New Tentative Standards:

The committee is proposing for publication as tentative the following seven methods, as appended hereto,[1] which have been edited in A.S.T.M. form by Subcommittee II, Editorial (E. P. Partridge, chairman), for general application to the analysis of industrial water:

Tentative Methods of Sampling Plant or Confined Waters for Industrial Uses, proposed by Subcommittee III on Methods of Sampling (R. E. Hall, former chairman). These methods are designed to furnish general technical information for securing representative samples of water for analysis. The information contained in the methods has been obtained in part from miscellaneous technical sources and in part from the experience of committee members;

Tentative Method for the Determination of Calcium Ion and Magnesium Ion in Industrial Waters, and Tentative Method for the Determination of Chloride Ion in Industrial Waters, proposed by Subcommittee IV on Methods of Analysis (J. R. McDermet, chairman), following a review of the technical literature;

Tentative Method for the Determination of Total Carbon Dioxide and Calculation of Carbonate and Bicarbonate Ions in Industrial Waters, and Tentative Method for the Determination of Hydroxide Ion in Industrial Waters, developed for use in the analysis of boiler water by Subcommittee 8 of the Joint Research Committee on Boiler Feedwater Studies, publication of which was made in pamphlet form by the American Society of Mechanical Engineers in September, 1933. These methods were accepted in substance by Subcommittee IV on Methods of Analysis; they were published[1] by the A.S.T.M. as information in October, 1936, and have been re-edited for publication as tentative. These methods, edited in different form, have appeared in Standard Methods for Water Analysis, published from the original by the American Public Health Association, 8th Edition, 1936;

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[1] See pp. 1263 to 1288.

Tentative Method for the Determination of Total Orthophosphate and Calculations of the Respective Orthophosphate Ions in Industrial Waters, and Tentative Method for the Determination of Sulfate Ion in Industrial Waters, prepared from various technical sources by Subcommittee IV on Methods of Analysis. These gravimetric methods were published as information by the Society in October, 1936, and have been re-edited for publication as tentative.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 55 members; 38 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
NEW TENTATIVE STANDARDS			
Methods of Sampling Plant or Confined Waters for Industrial Uses	37	0	1
Method for the Determination of Calcium Ion and Magnesium Ion in Industrial Waters	36	1	1
Method for the Determination of Chloride Ion in Industrial Waters	33	1	4
Method for the Determination of Total Carbon Dioxide and Calculation of Carbonate and Bicarbonate Ions in Industrial Waters	33	1	5
Method for the Determination of Hydroxide Ion in Industrial Waters	33	0	5
Method for the Determination of Total Orthophosphate and Calculation of the Respective Orthophosphate Ions in Industrial Waters	32	2	4
Method for the Determination of Sulfate Ion in Industrial Waters	34	2	2

RESEARCH ACTIVITIES

Silica in the Presence of Phosphate.—Committee D-19 transmitted a recommendation to the Joint Research Committee on Boiler Feedwater Studies that it consider research leading to the development of a colorimetric method for the determination of silica in the presence of phosphate. Favorable action has been taken by the Joint Committee on this recommendation.

Hardness Test of Water.—Because of the wide use of this informative test in all fields of industrial water (although it is not an exact determination), Subcommittee IV on Methods of Analysis may undertake a limited research investigation on hardness. The subcommittee has available replies to a questionnaire circulated among the committee members as well as the results of a research investigation conducted in the laboratories of the members.

Research on pH.—The committee learned informally, early in 1937, of the comprehensive and fundamental program on the subject of pH that is being conducted at the National Bureau of Standards. In view of the interest in this subject a paper on "The Need for pH Standards," by Baker Wingfield, W. H. Gross, Walter J. Hamer, and S. F. Acree, members of the Bureau's staff was presented at the session on water at the 1937 annual meeting of the Society.[2] In studying this project, the Advisory Committee of Committee D-19 reached certain conclusions concerning the need for standardization of pH measurements which they reported to Committee E-9 on Research as follows:

> 1. The proper significance and interpretation of the pH value of a solution, whether it be aqueous or non-aqueous, depends on the degree of precision of the measurement.

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[1] Available as separate reprint, October, 1936.

[2] Published in ASTM BULLETIN, No. 90, January, 1938, p. 15.

Technique of measurement and equipment for the test differ widely, and the user is confused by lack of standards.

2. The measurement of pH is one of the significant items in studying corrosion of metals exposed either to atmospheric or to sub-aqueous environments, and at differing temperatures. The measurement is widely used in the control of chemical and industrial processes. In the field of analytical water chemistry, it permits a more correct interpretation of the substances dissolved therein.

3. It is highly desirable that the fundamental characteristics outlined in the project be studied, and the information be made available for a more fundamental understanding of the physical and chemical characteristics of water and other fluids, as a basis for standardization.

4. The National Bureau of Standards, because of the extensive facilities available, is the logical agency to carry out the suggested program of research.

This matter has been referred by Committee E-9 to the standing committees of the Society to ascertain the extent of interest of the Society's committees in the project.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Policy and Procedure (F. N. Speller, chairman).—This subcommittee, as mentioned earlier in the report, has been discontinued and its functions assumed by the Advisory Committee. During the year a special committee of Subcommittee I made a study of the National Bureau of Standards research project on pH measurements and submitted its conclusion concerning the need for standardization of these measurements to Committee E-9 on Research, as mentioned above. This subcommittee has recommended to the Joint Research Committee on Boiler Feedwater Studies that the Research Committee study the factors involved in developing a colorimetric method for the determination of silica in the presence of phosphates and a method for the determination of hardness of water, either a soap or an equivalent test. Subcommittee I has also made certain recommendations which have resulted in a simplification of the subcommittee structure of Committee D-19.

Subcommittee II, Editorial (E. P. Partridge, chairman).—During the current year this subcommittee has edited in A.S.T.M. form the seven new methods which are being proposed for publication as tentative, as mentioned earlier in this report.

Subcommittee III on Methods of Sampling (M. A. Krimmel, chairman).—A meeting of this subcommittee was held in New York City in June, 1937. The subcommittee, while under the chairmanship of R. E. Hall, referred to the Editorial Subcommittee the substance of the new Tentative Methods of Sampling Plant or Confined Waters for Industrial Uses, which are being recommended for publication as tentative, as appended hereto.[1] A few minor items have been included in the methods since their acceptance by Committee D-19 at the June, 1937, meeting.

The subcommittee has accumulated published information on the sampling of water and steam, and arrangements are being made for the study and summarization of this material for use in the development of methods for the sampling of water and of steam, when such supplies are removed from equipment operating at atmospheric, superatmospheric and subatmospheric pressures.

Subcommittee IV on Methods of Analysis (J. R. McDermet, chairman).—This subcommittee held a meeting in New York City in June, 1937. The subcommittee completed the substance of the new Tentative Methods for the Determination of Calcium, Magnesium, and Chloride Ions in Industrial Waters, and referred them to Subcommittee II for editing. These methods are being recommended for publication as tentative, as appended hereto.[2]

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[1] See p. 1263.

[2] See pp. 1270 to 1276.

During the current year material has been secured for the preparation of additional methods, including referee and field methods for the determination of dissolved oxygen in water, for iron, alumina, and manganese, and for the improvement of the present field method for the determination of hardness in water as well as an equivalent titration method. The project on dissolved oxygen includes consideration of improved methods recently made available for this determination.

Concerning the project on iron, alumina, and manganese, a study will be made of the available methods in general use.

Concerning the hardness test, a study will be made of the replies received from the members to a request for information concerning the current practice in the use of the existing method for hardness testing by the use of soap. Contributions have been made available from a few of the members using a titration method for the determination of hardness. These will be studied as a means of field test for hardness to supplement the soap hardness test or to supplant it.

Subcommittee V on Classification (R. C. Adams, chairman).—The organization of this subcommittee resulted from action taken following the Round-Table Discussion on Interpretations of Water Analyses from Analytical Data, held during the meeting of Committee D-19 in New York City in June, 1937. The scope of Subcommittee V is as follows:

Scope.—The development of specifications for expressing the analytical data and methods for interpreting the analysis of water as a basis for classifying its probable behavior with respect to corrosion, deposition of solids when heated or processed, or other effects which are significant in determining the suitability of the water for industrial use.

A study may be made of the available literature on this subject.

A questionnaire is being conducted in the subcommittee to ascertain the reaction of the members to expressing the results of the water analysis in the ionic or the molecular form of the quantitative value, that is, parts per million of the substance by weight, or the mixed term of weight per unit of volume.

The election of officers for the ensuing term of two years resulted in the continuance in office of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 55 members; 38 members returned their ballots, of whom 32 have voted affirmatively and 0 negatively.

Respectfully submitted on behalf of the committee,

MAX HECHT,
Chairman.

R. E. HALL,
Secretary.

REPORT OF COMMITTEE D-20
ON
PLASTICS

Committee D-20 on Plastics was organized at a meeting in New York City on July 1, 1937, to undertake work in this rapidly developing field. Two further meetings of the committee have also been held: one in New York City on October 27, 1937, and the other in Rochester, N. Y., on March 9, 1938. At these meetings, the organization of the various subcommittees and sections, and the planning of the detailed programs for work have been completed, subject to change with future development. The work itself, along many different lines as described below, is now under way.

The following statement of scope of the work of the committee has been adopted:

> *Scope.*—The development of test methods applicable to the finished products (molding materials, sheets, tubes and rods, and molded or fabricated articles) in the field of plastics. The scope does not include electrical tests, and materials used in the paint industry and rubber industry, which are covered by other committees.

An important accomplishment for the year was the sponsoring of a Symposium on Plastics[1] held at the Ninth Regional Meeting of the A.S.T.M. in Rochester on March 9, 1938. The purpose of this symposium, which comprised six technical papers, was to discuss the significant properties of plastics and the various methods available for determining these chemical and physical properties. The preparation of these papers helped to crystallize a number of ideas on matters of interest to the committee, and discussion of them brought out further valuable information.

The present membership of the committee totals 47; of whom 23 are classified as producers, 15 as consumers, and 9 as general interest members.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Strength Properties (H. M. Richardson, chairman) has organized two sections which are actively engaged in studies of methods of measuring flexural and tensile strength, and methods of measuring resistance to impact.

Subcommittee II on Hardness Properties (J. C. Pitzer, chairman) is working on the development of methods for measuring indentation hardness, abrasion resistance, cold flow, and machinability, each being in charge of a section of the subcommittee.

Subcommittee III on Thermal Properties (L. M. Currie, chairman) held two formal meetings during the year. The first, held in New York City on October 27, 1938, was a strictly preliminary organization meeting. The second, held in Rochester, N. Y., on March 10, 1938, followed the Plastics Symposium, before which two members of the subcommittee presented papers.

At the first meeting, the scope of Subcommittee III was clearly defined and limited. Based on prior correspondence the interest of the subcommittee members was determined as falling naturally into five sections as indicated below. Representative members of the subcommittee were asked to make further study of the problems covered by the five general sections. At the Rochester meeting the different section chairmen made their reports, as follows:

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[1] Symposium on Plastics, Rochester Regional Meeting, Am. Soc. Testing Mats., (1938). (Available as separate publication.)

Section A on Heat Distortion (Robert Burns, chairman),
Section B on Thermal Expansion and Conductivity (A. B. Cummins, chairman),
Section C on Flammability (W. A. Zinzow, chairman),
Section D on Molded Factors and Plasticity Relations (L. W. A. Meyer, chairman), and
Section E on Changes on Heating (H. R. Dittmar, chairman).

The subcommittee showed reasonable unanimity of opinion with regard to the first four sections and immediate efforts will be made to institute a round-robin series of tests and test materials for evaluation by the different members. In the case of Section E, it has been agreed that practically all of the work more properly falls within the scope of Subcommittee V to whom the work has been transferred with the proferred assistance of Subcommittee III.

It is hoped that, prior to the fall meeting of the subcommittee, definite results can be shown in the work of the first four sections.

Subcommittee IV on Optical Properties (H. W. Paine, chairman) held two meetings during the year. The first meeting was held on October 27, 1937, and was mainly devoted to organization. Sections were appointed on index of refraction, surface irregularities, polarization, haze, clarity, optical efficiency, and surface brightness. Chairmen of the sections were requested to report their work in writing by January 15, which was done in most cases, and their reports were discussed at the second meeting held in Rochester, N. Y., on March 9 and 10, 1938.

At that time an optical report was received, and further studies are to be made on clarity and haze. Reports on optical efficiency and surface brightness were also presented. A method for measuring optical efficiency was chosen. Surface brightness and several other surface pehnomena were referred to the sections of the committee who are to discuss the tests with a committee of the Illuminating Engineering Society.

A report on index of refraction, surface irregularities, and polarization was also presented, and two methods were chosen for submission to letter ballot of the subcommittee.

The questions of terminology of surface irregularities and methods of measuring surface irregularities of opaque materials are to be submitted to Committee D-20 for comment.

Subcommittee V on Permanence Properties (G. M. Kline, chairman) at its organization meeting on October 27, 1937, appointed four sections to develop methods for determining the effects of various chemical and physical agents on plastics, as follows:

Section 1 (M. H. Bigelow, chairman) to consider the effect of light in all its aspects, including sunlight, ultraviolet light, intense artificial light, and the like,

Section 2 (C. A. Nash, chairman) to consider the effect of continuous exposure at various temperatures, including elevated and low temperatures,

Section 3 (W. J. Clarke, chairman) to consider the effect of different humidity conditions and water, including outdoor exposure, and

Section 4 (H. F. Neindl, chairman) to consider the effect of chemical reagents, including strong and weak acids and alkalies, typical solvents, salt solutions, and various corrosive gases.

Reports from the chairmen of these four sections were discussed at the second meeting of the subcommittee in Rochester on March 10. Preliminary drafts of methods for determining the effect of chemical reagents on plastics and for measuring the absorption of water by plastics were formulated. Tests to determine the suitability of the proposed procedures for use with the different types of commercial plastics are under way.

In much of this work the committee is glad to acknowledge the active cooperation of various members of Committee D-9 on Electrical Insulating Materials. Arrangements are being completed for cooperative work on the optical properties of plastics with the Illuminating Engineering Society.

The election of officers for the ensuing term of two years resulted in the reelection of the present incumbents.

This report has been submitted to letter ballot of the committee, which consists of 47 members; 29 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

W. E. EMLEY,
Chairman.

W. A. EVANS,
Secretary.

REPORT OF COMMITTEE E-1
ON
METHODS OF TESTING

The Advisory Committee of Committee E-1 on Methods of Testing held a meeting in New York City on July 1, 1937. A meeting of the main committee is to be held this year during the annual meeting in Atlantic City, N. J., subsequent to the presentation of this report to the Society.

The Executive Committee of the Society appointed three representatives-at-large to serve on the Advisory Committee, namely, T. A. Boyd, General Motors Corp., D. E. Douty, United States Testing Co., and R. L. Templin, Aluminum Company of America, each for three-year terms, expiring in 1940.

At the July, 1937, meeting of the Advisory Committee approval was given to the formation of a technical committee under Committee E-1 looking toward the establishment of standard atmospheric test conditions, including both humidity and temperature, with the functions as outlined in the report of Committee E-1 last year.[1] The proposed committee has been designated Technical Committee X on Conditioning and will function under the chairmanship of Robert Burns of the Bell Telephone Laboratories. Announcement of the authorization of this committee has been made to the standing committees of the Society and representatives from several of the interested committees have been appointed. The personnel of the committee to date, including special adviser-members and committee representatives, is as follows:

Robert Burns (Chairman), Bell Telephone Laboratories,
R. H. Brown, representing Committee D-13 on Textile Materials,
R. W. Carlson, representing Committee C-9 on Concrete and Concrete Aggregates,
E. H. Dix, Jr., representing Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys,
J. R. Dwyer, representing Committee C-1 on Cement,
W. H. Finkeldey, representing Committee B-3,
*G. H. Mains, National Vulcanized Fibre Co.,
*H. A. Nelson, New Jersey Zinc Co.,
*L. S. Reid, Metropolitan Life Insurance Co.,
E. O. Rhodes, representing Committee D-4 on Road and Paving Materials,
*A. E. Stacey, Jr., Buensod-Stacey Air Conditioning, Inc.,
*C. G. Weber, National Bureau of Standards,
J. M. Weiss, representing Committee D-8 on Bituminous Waterproofing and Roofing Materials, and
*C. N. Wenrich, Armstrong Cork Co.

* Special Adviser-Member.

The organization meeting of the technical committee is to be held during this annual meeting of the Society.

During the year, the Executive Committee of the Society has assigned to Committee E-1 the task of reviewing glass apparatus with the transfer of activities of the former Committee D-15 on Thermometers and Laboratory Glassware to a new E-1 technical committee, designated Technical Committee XII on Laboratory Glassware under the chairmanship of W. H. Fulweiler. The organization and activities of this technical committee are discussed in detail later in this report.

Subsequent to the 1937 annual meeting, Committee E-1 presented to the Society through Committee E-10 on Standards a revision of the Tentative

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 508 (1937).

Definitions of Terms Consistency and Plasticity (E 24 - 34 T). The revised definitions, entitled "Tentative Definitions of Terms Relating to Rheological Properties of Matter," were accepted[1] by Committee E-10 on October 11, 1937, and appear in the 1937 *Proceedings*.[2]

ACTIVITIES OF TECHNICAL COMMITTEES

Technical Committee I on Mechanical Testing (H. F. Moore, chairman):

As usual the report of this committee consists of brief summaries covering the work of its various sections during the year.

Section on Tension Testing (R. L. Templin, chairman).—This section held a meeting in Rochester, N. Y., on March 9, 1938. At that meeting progress was reported on the cooperation with a subcommittee of Committee A-1 on Steel in connection with considerations being given to methods of testing pipe.

The effect of speed of testing on results of tests has become a major problem with this section as it has with several others, the interested sections maintaining close contact with the Section on Effect of Speed of Testing.

The section has given consideration to the desirability of having more definite specifications for subsize tension specimens than the general rule of geometrical similarity of standard machined specimens now gives. A subgroup of the section has this matter under consideration.

Section on Compression Testing (M. F. Sayre, chairman).—This section held a meeting in New York City on June 30, 1937, during the annual meeting of the Society. The section has been working in cooperation with Committee B-5 on Copper and Copper Alloys in connection with the compression requirements for rolled, non-ferrous bearing plates for bridge and other structural uses. The section has also appointed a group to consider editorial revisions in certain specifications to make them conform to recent changes in nomenclature. This section is also keeping in very close touch with the Section on Effect of Speed of Testing, and in this connection was interested in the paper by Paul G. Jones and F. E. Richart entitled "The Effect of Testing Speed on Strength and Elastic Properties of Concrete,"[3] presented at the 1936 annual meeting of the Society.

Section on Bend Tests for Ductility (A. B. Kinzel, chairman).—A subgroup of this section has been continuing its study of the Erichsen and Olsen ductility testers and is presenting a report on this subject entitled "Report on Study of Cup Testing of Sheet Steel" which is appended hereto. A questionnaire as to the continuance of this work either in the ferrous or non-ferrous fields has shown that there is very little real interest in this subject and it has accordingly been decided that no further work will be undertaken; the accompanying report may, therefore, be considered as a final report of the subgroup.

The section has continued its study of bend tests for ductility and has approved a revision of the Tentative Method of Bend Testing for Ductility of Metals (E 16 - 31 T)[4] which, after approval by Committee E-1, is to be submitted to Committee E-10 on Standards so that the method may be published in its revised form during the year.[5] This proposed revision, which is given in detail below, is based on the recommendations of a special committee, under the chairmanship of Prof. M. F. Sayre and sponsored by the American Welding Society, which has recently reviewed various codes and specifications with the object of coordinating these and, wherever possible, obtaining modification so as to make the various standards consistent in this respect. In considering the bend test the special committee reports that there is appreciable variation among the various codes and specifications with respect to the ratio of width to thickness of the specimens. The A.S.M.E. Boiler Code Committee uses a width to thickness ratio of $1\frac{1}{2}$, while Method E 16 recommends 3 to 1. The British recommend 5 to 1, and certain other codes in this country recommend as low as 1 to 1. In the work carried out by the Section on Bend Tests at the time Method E 16 was developed, it was shown that with material of varying thickness having the same mechanical properties, the bend test results are within the limits of accuracy of 5 per cent with the 5 to 1 ratio. With greater ratios this figure may be lowered to 3 per cent, and with smaller ratios, such as the $1\frac{1}{2}$ to 1, it increases and may show as much as 15 per cent variation between thin and thick specimens.

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[1] In submitting this recommendation to Committee E-10 on Standards, Committee E-1 reported results of the letter ballot vote as follows: Of a total membership of 52, 44 members returned their ballots, of whom 30 voted affirmatively, 3 negatively, and 11 members marked their ballots "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1300 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 1556.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part II, p. 380 (1936).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 1034 (1931); also 1937 Book of A.S.T.M. Tentative Standards, p. 1496.

[5] See Editorial Note, p. 489.

In view of the much greater ease of handling the thick specimens where a ratio of $1\frac{1}{2}$ instead of 3 is involved, there is merit in the Boiler Code requirement of $1\frac{1}{2}$ and in having the A.S.T.M. change its requirement of width to thickness ratio from "3" to "$1\frac{1}{2}$," this being done with the full knowledge that, while the duplicability of results on similar material of given thickness is not changed, higher values will be obtained in the thicker material. It is understood that the various code bodies in the United States have indicated that they would change their required width to thickness ratio to $1\frac{1}{2}$, and Committee E-1 has likewise been requested to consider this action.

In view of the fact that the major feature of any test is that it be standardized and duplicable on a given specimen, it would appear that the matter of more precise duplicability in material of varying thickness might be waived in order to give to the engineering profession a series of specifications which are identical in essence and thus avoid confusion. The detailed changes to be proposed in Method E 16 are as follows:

Section 2 (a).—Change the first sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

> For results in which the measured performance is independent of the thickness of the specimen, rectangular specimens with widths at least [three] *one and one-half* times the thickness shall be used.

Section 6.—Change the first sentence to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

> The duplicability of the test results as obtained by this procedure when applied to rolled steel plate will be within [5] *15* per cent of the fiber elongation.

Section on Indentation Hardness (J. R. Townsend, chairman).—This section held a meeting in New York City on June 30, 1937, during the annual meeting of the Society, at which the question of a scratch hardness test was discussed. Subsequently a Proposed Method of Test for File Scratch Hardness of Metallic Materials, described by W. C. Hamilton of the American Steel Foundries, was approved by letter ballot for publication as information.[1]

At the June meeting the section also discussed the standardization of Rockwell hardness machines over certain ranges. The variability of hardness of test blocks in some ranges seems to be a matter requiring investigation.

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[1] See ASTM BULLETIN, No. 88, October, 1937, p. 26.

Section on Testing Thin Sheet Metals (C. H. Marshall, chairman).—This section has undertaken no new work since the publication last year of the report on "Usefulness and Limitation of Various Tests as Applied to Sheet Metals."[1] A suggestion has been made that the work of the section be continued by studying one or two of the most widely used tests for sheet metals to a point where definite recommendations with respect to test methods could be proposed. The opinion of the members is now being solicited on this proposal.

Section on Flexure Testing (H. F. Clemmer, chairman).—This section was directly instrumental in arranging for the presentation at the 1937 annual meeting of the Society of the paper by J. T. MacKenzie and C. K. Donoho on "A Study of the Effect of Span on the Transverse Test Results for Cast Iron."[2]

Section on Impact Testing (W. W. Werring, chairman).—This section held a meeting in New York City on July 1, 1937, during the annual meeting of the Society, at which the Tentative Methods of Impact Testing of Metallic Materials (E 23 - 34 T) were considered and in this connection the committee discussed the desirability of rewriting the methods to include tension impact, possibly torsion impact, and also other type specimens such as the keyhole notch specimen for which considerable demand has developed. The standard is to be made as informative as possible on the effects of notches, velocity, and other factors.

This section is sponsoring a Symposium on Impact Testing[3] to be held at this annual meeting of the Society. The symposium, arranged jointly by the Society and the Engineering Foundation's Welding Research Committee, which is sponsored by the American Welding Society and the American Institute of Electrical Engineers, presents an integrated series of papers covering the basic theories underlying impact tests, data on the factors affecting impact, and papers covering the practical application of impact tests to metals, organic plastics, and welds.

Section on Effect of Speed of Testing (P. G. McVetty, chairman).—This section held a meeting in Rochester, N. Y., on March 9, 1938, at which preliminary plans were made to sponsor an investigation on the effect of speed of testing on the physical properties of metals. The necessity for such an investigation has become more and more apparent as the work of the section has progressed. The proposed study is to include a series of tests on metals similar to that on the "Effect of Speed of Testing Concrete" by Paul G. Jones and Frank E. Richart, reported in 1936,[4] and on "Short-Time Creep Tests of Concrete in Compression," by Russell S. Jensen and Frank E. Richart to be reported at this annual meeting.[5] In order to finance this investigation a request has been made of the A.S.T.M. Research Fund for an appropriation of $600. It is hoped that it may be possible to carry out such a series of tests, in which speed effects on the testing machines are eliminated as far as possible, and which shall serve as a basis for deciding what methods of expressing speed of testing are best for specifications and what tolerances for speed limitation seem necessary.

This section maintains close contact with the work of the Sections on Tension Testing and on Compression Testing.

Section on Elastic Strength of Materials (F. B. Seely, chairman).—This section held a meeting in Rochester, N. Y., on March 10, 1938, at which the question of assembling as information a series of typical stress-strain diagrams for various materials was further discussed. This matter is still being considered by a special subgroup of the section.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 518 (1937).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part II, p. 71 (1937).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, pp. 21 to 156 (1938.

[4] *Loc. cit.*

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 410 (1938).

There has been referred to the section by Committee E-8 on Nomenclature and Definitions the question of preparing an authoritative definition for the term "creep." This term has been most generally used in connection with the change that takes place in metals under stress at high temperatures. There was an interesting discussion of it in connection with the paper on "Measuring Elastic Drift" by R. W. Carson, presented at the 1937 annual meeting.[1] The section discussed this matter at its meeting in March and it was the consensus that the simple definition given by Mr. Carson in his closure[2] of the discussion of his paper was preferable; no action was taken, however, there being some doubt as to whether the subject of creep comes within the province of this section.

Section on Calibration of Testing Machines (H. F. Moore, chairman).—This section held a meeting in Rochester, N. Y., on March 10, 1938, at which it had been planned to initiate a discussion of the calibration of strain-measuring apparatus but, unfortunately the material necessary for this discussion was not received in time for consideration at the meeting. The question of the available facilities for the standardization of proving rings for testing machines was considered, and also the possibility of satisfactory standardization of these rings by other than dead-weight measurements. The practice of the British National Physical Laboratory in using a single-lever testing machine as a primary standard was cited, and the possibility of using a multiple-lever beam-balance testing machine kept for the special purpose of standardization and used merely as a transfer instrument, was also discussed.

Technical Committee II on Consistency, Plasticity, and Related Properties (E. C. Bingham, chairman):

The Tentative Definitions of Terms Relating to Rheological Properties of Matter (E 24 – 37 T), which were accepted for publication last year through Committee E-10 on Standards, as mentioned earlier in this report, have been circularized for criticism and comment among the standing committees of the Society. A number of constructive comments have been received and are to be considered by the technical committee at a meeting to be held in June. Discussion of the definitions has also been continued in the Society of Rheology and with interested European investigators.

A Special Committee has been organized, under the chairmanship of T. H. Rogers of the Standard Oil Co. of Indiana and composed of representatives of the interested standing committees, for the purpose of considering certain features of the Tentative Method of Test for Softening Point by Tapered Ring Apparatus (E 28 – 36 T)[3] in view of the various comments received concerning the method. The Special Committee held a meeting in Rochester, N. Y., on March 9, 1938, and agreed on certain proposed revisions, as indicated below, which were subsequently confirmed by letter ballot of the Special Committee. These revisions, after approval by Committee E-1, may be submitted to Committee E-10 on Standards so that the method may be published in its revised form during the year.[4]

Title.—Change to read as follows by

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part II, p. 661 (1937).

[2] *Ibid.*, p. 673.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1186 (1936); also 1937 Book of A.S.T.M. Tentative Standards, p. 1527.

[4] These proposed revisions were not acted upon in 1938 and are to receive further consideration in the committee before being presented to the Society.

the addition of the italicized words and the omission of the word in brackets:

> Tentative Method of Test for Softening Point [by] (*Ball and* Tapered Ring Apparatus).

Section 3.—Change the second and third sentences to read as follows by the addition of the italicized words and the omission of the words and figures in brackets:

> A quantity at least twice that necessary to fill the desired number of rings and in no case less than 40 g. shall be melted immediately in a clean container, using an oven, *hot plate,* sand or oil bath to prevent local overheating. Care shall be taken to avoid incorporating air bubbles in the sample, [which should not be heated more than 30 C. (54 F.) above its softening point, in the case of materials having a softening point below 121 C. (250 F.), except rosin, or more than 50 C. (90 F.) for rosin and materials with softening points above 121 C. (250 F.), for materials having a long softening range it may be necessary to increase this to 85 C. (185 F.)] *which shall not be heated above the temperature necessary to pour the material readily without inclusion of air bubbles.* The time from the beginning of heating to the pouring of the sample *shall* not [to] exceed 15 min.

Fig. 2.—It is proposed to revise the design of the ball-centering guide to show the use of round openings in the side of the guide rather than square openings, in order to facilitate its manufacture.

Section 4 (a).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 4. (*a*) Assembling Apparatus.—The glass container shall be filled to a depth not less than 9 cm. (3.5 in.) with freshly boiled distilled water (or with glycerin for materials melting above 80 C. (176 F.)) which has been cooled to not less than 45 C. (81 F.) below the anticipated softening point but in no case lower than 5 C. (41 F.) for materials melting below 80 C. (176 F.) and in no case lower than 35 C. (95 F.) for materials melting above 80 C. (176 F.). ***Provision shall be made for centering the ball on the upper surface of the sample, either by use of the ball guide or by making a slight indentation in the center of the sample. The latter may be done by pressing the ball or a rounded rod into the material at this point. In the case of hard materials the rod may be heated.*** The ring containing the sample and ball guide, ***if used,*** shall be suspended in the water so that the lower surface of the filled ring is 2.5 cm. (1 in.) above the bottom of the glass container (Fig. 1) or 2.5 cm. above the upper surface of the lower horizontal plate which is at least 1.3 cm. ($\frac{1}{2}$ in.) above the bottom of the glass vessel (Fig. 3) and so that its upper surface is at least 5.1 cm. (2 in.) below the surface of the water. The ball shall be placed in the water but not on the specimen. The thermometer shall be suspended so that the bottom of the bulb is level with the bottom of the ring and within 1.0 cm. ($\frac{3}{8}$ in.) but not touching the ring. The initial temperature shall be maintained for 15 min. With suitable forceps the ball shall be placed in the center of the upper surface of the material in the ring [using the ball guide to hold the ball in this position].

Technical Committee III on Particle Size and Shape (L. T. Work, chairman):

During the past year there have been no special developments in the Sections on Fine Sieves and on Coarse Screens as the sections have been awaiting the approval by Sectional Committee Z23 on Sieves for Testing Purposes, of the proposed American Standard for Sieves for Testing Purposes, which will represent a revision of the A.S.T.M. Standard Specifications for Sieves for Testing Purposes (E 11 – 26), and for Round-Hole Screens for Testing Purposes (E 17 – 36).[1] The issues have been quite thoroughly resolved in the sectional committee and the changes to be made in the present A.S.T.M. specifications are not particularly significant. The main effect may be the coordination of specifications for coarse and fine sieves into a common standard. A meeting of the technical committee will be held in June for a full discussion of all phases of the committee's work.

The Section on Subsieve Sizes under the chairmanship of D. L. Gamble, is considering a revision of the present Tentative Method of Analysis for the Particle Size Distribution of Subsieve Size Particulate Substances (E 20 – 33 T) and a program of correlation of methods now coming into use for subsieve-size measurement.

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[1] See Editorial Note, p. 489.

Technical Committee IV on Methods for Density (H. W. Bearce, chairman):

The various methods of test for density, specific gravity, and unit weight prescribed in the standards of the Society are being reviewed by the members of this technical committee for the purpose of preparing recommended changes and improvements, in the interest of having all descriptions of such tests theoretically and basically correct.

Technical Committee IX on Interpretation and Presentation of Data (H. F. Dodge, chairman):

The Round-Table Discussion on the subject of "Precision and Accuracy," conducted jointly by this technical committee and Technical Committee XI on Designation and Interpretation of Numerical Requirements during the 1937 annual meeting, was well attended. Following the presentation of three informal papers by W. A. Shewhart, H. F. Moore, and G. E. F. Lundell, and discussions of these papers individually by R. F. Passano, H. J. Ball, and H. V. Churchill, there followed an extended general discussion of the inconsistencies of usage of these two terms. At the conclusion of the meeting, the following resolution for submission to Committee E-1 was adopted:

> *Resolved,* that when a standing committee records or specifies a numerical value for precision in a standard, the committee should make clear what is meant in terms of operations or procedures to be followed for purposes of verification.

During the past year, 15 requests for information or recommendations with respect to methods of using statistical techniques have been received by the technical committee, some from committees of the Society and others from outside individuals or organizations. It is interesting to note that the questions raised have, to a larger extent than heretofore, related to problems of preparing specifications rather than to problems of controlling quality in production or of interpreting data. This tendency is considered of some significance in view of the fact that the three coordinate steps of quality control, namely, specification, production, and inspection, are considered by the committee to be rather closely interlocked and not independent of one another, as they are frequently thought to be. The numerical limits specified for quality characteristics depend on manufacturing capabilities and controls, and the acceptance requirements imposed on test and inspection samples must, in turn, if they are to prove economical, depend closely both on the specified limits and on the levels of control attained in production. There is evidence of a growing appreciation of the part to be played by statistical methods at each of these three steps, especially where mass production and sampling are involved.

Technical Committee XI on Designation and Interpretation of Numerical Requirements (J. A. Gann, chairman):

The Proposed Recommended Practices for Designation of Numerical Requirements in Standards, with illustrative specifications, which were circularized during the year among the standing committees of the Society, have elicited great interest and as a result many comments and suggestions concerning the recommended practices have been received. Some of the comments advanced will require careful consideration in order to be certain that Technical Committee XI is in accord as to the best method of procedure. The various suggestions are to be considered by the technical committee at a meeting to be held this June.

Technical Committee XII on Laboratory Glassware (W. H. Fulweiler, chairman):

As mentioned earlier in this report, this technical committee has been created to take over the activities of the former Committee D-15 on Thermometers and Laboratory Glassware. For some time Committee D-15 had felt that it would be desirable to have more definite control over requirements for laboratory apparatus as developed by the individual standing committees of the Society. When the scope of Committee D-15 was extended in 1933 to include laboratory glassware, a number of apparatus manufacturers were added to the committee personnel, and also representatives of some of the standing committees more directly concerned with this type of apparatus. While the committee has been in a position to do some very constructive work in reviewing requirements, nevertheless these reviews have frequently had to be made after the method, in which the requirements appeared, had been approved by the Society as tentative, or even as standard. It is felt that this new set-up under Committee E-1 will afford a more effective tie-in between the reviewing committee on apparatus and the individual standing committees.

Technical Committee XII was organized at a meeting held in Rochester, N. Y., on March 10, 1938, with the personnel of the former Committee D-15[1] as a nucleus. Invitations have been extended to the interested standing committees not already represented on the committee to designate representatives thereon. To date the following appointments have been made:

J. R. Dwyer, representing Committee C-1 on Cement,
C. A. Hogentogler, representing Committee D-18 on Soils for Engineering Purposes,
W. A. Selvig, representing Committee D-5 on Coal and Coke, and
F. W. Smither, representing Committee D-19 on Water for Industrial Uses.

The work of the technical committee is to be handled by the following four subcommittees which are in course of organization:

Section A on Thermometers (R. M. Wilhelm, chairman),
Section B on Hydrometers (J. P. Bader, chairman),
Section C on Volumetric Glassware (J. J. Moran, chairman), and
Section D on Laboratory Glassware (F. F. Shetterly, chairman).

Individual specifications are to be prepared covering each thermometer now specified in existing A.S.T.M. standards and tentative standards. At the request of Committee D-1 on Paint, Varnish, Lacquer, and Related Products, specifications for special thermometers for turpentine distillation are to be studied and prepared.

The proposed test for dropping point of grease has been reviewed by Technical Committee XII and referred to Subcommittee I for study and to prepare eventually detailed specifications for a suitable thermometer for this test. The committee has also discussed thermometers for use in distillation tests of solvents and diluents used in the manufacture of paints and lacquers.

The technical committee is sponsoring the preparation of three technical papers on the testing of various types of glassware apparatus. The first of these, on "Methods of Testing Thermometers," by E. F. Mueller and R. M. Wilhelm appears as an Appendix to this report. A second paper on "Testing of Hydrometers," by E. N. Hurlburt is contemplated for presentation next year, and a third on "Testing Calibrated Glass Apparatus," by J. J. Moran is planned for 1940.

At the request of Technical Committee XII the Society has asked the National

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[1] See 1937 A.S.T.M. Year Book, p. 201.

Bureau of Standards to undertake, when thermometers are submitted to the Bureau to determine conformity or otherwise with A.S.T.M. standards, to issue a certificate which will state whether the thermometer does or does not conform to the A.S.T.M. standard and also to indicate with the certification the necessary corrections at the required test points.

The election of officers for the ensuing term of two years resulted in the reelection of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 47 members; 42 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

W. H. FULWEILER,
Chairman.

P. J. SMITH,
Ex-officio Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting, Committee E-1 on Methods of Testing presented to the Society on August 25, 1938, through Committee E-10 on Standards the following recommendations:

Proposed Tentative Specifications for Sieves for Testing Purposes (Wire Cloth Sieves, Round-Hole and Square-Hole Screens or Sieves) to replace immediately the Standard Specifications for Sieves for Testing Purposes (E 11 - 26) and for Round-Hole Screens for Testing Purposes (E 17 - 36), and

Proposed Revision of Tentative Method of Bend Testing for Ductility of Metals (E 16 - 31 T).

These recommendations were accepted by Committee E-10 and appear on pp. 1289 and 1298, respectively.

REPORT ON STUDY OF CUP TESTING OF SHEET STEEL

REPORTED BY SPECIAL COMMITTEE OF SECTION ON BEND TESTS FOR DUCTILITY

Introduction:

Subsequent to the formulation of a tentative method for bend testing[1] of plates and bars, this committee was requested to study the matter of a ductility test for sheets. The methods used in the bend test are in general not applicable to sheet because of the limited fiber elongation necessary for a flat bend and the high degree of ductility of most of the sheet materials that are to be tested. Accordingly, cup testing was envisaged and a special subcommittee, consisting of representatives of sheet steel producers, users, and testing machine manufacturers was organized. It was planned to limit the tests in question to sheet steel of the deep stamping type, and conclusions are necessarily limited to this type of material, although probably they may be extrapolated to other types of steels.

The first problem was the determination of the duplicability of results with previously standardized cup testing machines. There was no thought of attempting a correlation between cup test results and deep-drawing properties or any other property of sheet steel at this time. Under the auspices of the committee some 600 cup tests have been performed by various cooperating laboratories and attempts have been made to correlate the results.

Organization of Committee:

A special committee was organized to represent four laboratories that would cooperate in making Olsen tests, and four other laboratories cooperate in making Erichsen tests. One of the four in each case was designated as a reference laboratory, and the tests were planned so that the results obtained by the reference laboratory could be compared with those of the other three laboratories in each case.

The Tinius Olsen Testing Machine Co. was the reference laboratory for the Olsen ductility test, and the Allegheny Steel Co., The American Rolling Mill Co., and the Budd Manufacturing Co. were the corresponding cooperators.

In the case of the Erichsen test, the Union Carbide and Carbon Research Laboratories acted as the reference laboratory, and the Eastern Rolling Mill Co., Herman A. Holz, and the Packard Motor Car Co. were the corresponding cooperators.

Representatives from all eight of these laboratories had membership on the committee.

Procedure:

The general procedure for such series was to have each of the three cooperating laboratories for the Olsen test make tests on about 50 coupons cut from a sheet of automobile-body drawing steel. These coupons had been previously tested by The Tinius Olsen Co. This procedure required a full sheet for each of the three cooperating laboratories, making a total of six sheets in all. About 50 specimens, $3\frac{1}{2}$ by 8 in. were cut from each of these sheets after suitable discard of material at the edges and ends.

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[1] See Tentative Method of Bend Testing for Ductility of Metals (E 16 – 31 T), *Proceedings*, Am. Soc. Testing Mats., Part I, p. 1034 (1931); also 1937 Book of A.S.T.M. Tentative Standards, p. 1496.

Machines were checked by means of a template on the ball and die. The operators were instructed to check the zero reading, to wipe the steel dry with a rag, to make compressions on the numbered side, to center the strip $\frac{7}{8}$ in. from edge to edge, to bring the top die slowly down on the specimen and then pull up firmly, operating the hand wheel at about 27 r.p.m. and to refrain from backing off at all. It was suggested that the load at one-fourth cup depth and at fracture be read whenever possible. The operators were further instructed that fracture was to be considered the initial falling off of the load. The depth of the cup fracture was the main item to be recorded and the operators were further instructed to wipe specimens with an oily rag to prevent rusting immediately after removal from the machine. In view of the wide spread in readings obtained on supposedly similar specimens in a given laboratory and the still further spread between values obtained in reference laboratory and cooperating check laboratories, it was agreed to repeat the entire experiment, allowing the cooperating laboratories the privilege of readjusting their machines once again. The second series was started in November, 1933.

Results:

The results of the first series of tests were studied in great detail by various members of the committee prior to the inauguration of the second series. The committee was in agreement that all methods of calculation and plotting of the data failed to show satisfactory correlation between the different machines. This conclusion, in fact, was the reason for repeating the work, but the results of the second series, to all intents and purposes, were the same as the results of the first series.

Discussion:

As indicated above, the problem before the committee was to see whether or not the cup testing machines in use in the various laboratories would give comparable results on deep-stamping sheet, that is, if they would check each other within reasonable limits of accuracy. The numerical results of the two series of tests conducted by this committee show that even under the supposedly carefully controlled conditions, both with respect to adjustment of the machine and standardization of procedure, the spread in the values on any one machine as well as the difference in the probable value between machines in various laboratories is far beyond the limits which would be necessary for commercial specifications. This was brought out definitely in a statistical analysis of the results of the first series, and is equally evident in the comparative curves of the second series.

While it is true that, based on the depth of cup, the percentage error is of the order of magnitude of 5 to 10 per cent for a large proportion of the tests, this in itself has no significance, as 10 per cent means a difference of about 0.04 in. in the Olsen cup test and about 1 mm. in the Erichsen test. Obviously, this is much too great a difference for use for specification purposes, where deep-stamping quality or some other characteristic is to be indicated by an accurate index. The following quotation from the British Institute of Automotive Engineers, March, 1935, is of interest in this connection:

> From the evidence which has been placed before it, the committee, while appreciating the value of cupping tests, does not feel justified in recommending a test of this kind for specification purposes. There is no doubt that it does afford some indications of workability and ductility of thin metallic materials if the results are interpreted with discretion, but the test does not provide a reliable indication of the probable behavior of the material under cold-pressing and drawing operations.

It is appreciated that two questions are involved in this quotation: (1) the correlation of cup testing and deep-stamping property, and (2) the duplicability of cup testing results.

It is to be particularly noted that in addition to the cup depth, which is the value reported for these tests, there is much to be learned from the inspection of the cup and fracture. The nature of the Luders' lines, so-called "orange peel" effect, and the indication of the grain size are illustrative. It should further be noted that the conclusions are restricted to sheet steel, and it is well known that cup testing on non-ferrous materials, particularly brass and copper, is not necessarily subject to the same conclusions. For a critical discussion of the measurement of ductility testing of aluminum sheet, those interested are referred to a paper by R. L. Templin entitled "Ductility Testing of Aluminum and Aluminum Alloy Sheet."[1]

It is the considered opinion of the majority of this committee that the data obtained in this study were representative of actual conditions as they exist today with special reference to sheet steel and that these data warrant the conclusion that while cup testing may be useful as a qualitative indication of one kind of ductility of sheet steel and, on a statistical basis, may even provide a rough quantitative index, the use of individual cup tests for specification purposes is not to be recommended.

Respectfully submitted on behalf of the committee,

A. B. KINZEL,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part II, p. 239 (1936).

APPENDIX

METHODS OF TESTING THERMOMETERS

By E. F. Mueller[1] and R. M. Wilhelm[2]

The temperature scale generally used at present is the International Temperature Scale, adopted in 1927 by the Seventh General Conference of Weights and Measures, representing 31 nations. On this scale, temperatures in the interval 0 to 660 C. (32 to 1220 F.) are defined in terms of the resistance of a standard form of platinum resistance thermometer, calibrated at 0, 100 C., and the boiling point of sulfur (444.6 C.). Temperatures below 0 C. and down to −190 C. (−310 F.) are also defined in terms of the resistance of the standard resistance thermometer, using a different interpolation formula, which requires an additional calibration point at the boiling point of oxygen (−182.97 C.). The English version of the text adopted by the Conference of 1927 has been published by Burgess.[3] A few minor changes in wording were adopted by the Eighth General Conference in 1933.

The calibration of any liquid-in-glass thermometer consists in comparing its indications, directly or indirectly, with those of a standard platinum resistance thermometer. The present treatment of the subject will be limited to comparison of the thermometers to be tested with similar working standards which have been previously standardized against the resistance thermometer.

In selecting working standards, there is a choice between standards designed to attain the highest accuracy of which a liquid-in-glass thermometer is capable, and similar standards made to the same specifications as the thermometer to be tested. To compare a very high-grade standard with a thermometer of a different type requires, in general, a better comparison bath and more care in observation and computation than are required in comparing similar thermometers. The advantages from the standpoint of the industrial laboratory of using standards similar to the product to be tested are such that the present treatment will be confined to a description of comparisons of similar instruments.

Changes in Thermometers with Time and Use:

The bulb of a Centigrade mercury in glass thermometer has a volume equivalent to about 6000 deg. of the scale. It is obvious therefore that if the bulb of such a thermometer suffers a permanent change in volume of 1 in 6000, the readings will be changed by about 1 deg. and that if the corrections are to remain constant to 0.05 deg. the bulb must suffer no change as large as one part in 100,000. Similarly, the bulb of a Fahrenheit mercury in glass thermometer has a volume equivalent to about 11,000 deg. of the scale, so that if the corrections are to remain constant within 0.1 deg. the bulb must suffer no change as large as 1 in 100,000. Thermometer bulbs, whether used or not, may readily change in volume by as much as 1 in 100,000, and unless such changes are determined and allowed for, it is evident that accuracies of the order of 0.05 C. or

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[1] Physicist, National Bureau of Standards, Washington, D. C.

[2] Technical Adviser, C. J. Tagliabue Manufacturing Co., Brooklyn, N. Y.

[3] G. K. Burgess, "The International Temperature Scale," *Journal of Research*, Nat. Bureau Standards, Vol. 1, p. 635 (1928) (*Research Paper No. 22*).

0.1 F. cannot be maintained. Since the volume of the bulb is about 60 times the volume between the ice point and steam point graduations, it is also apparent that changes in the volume of the capillary will not affect the accuracy appreciably, unless such changes are proportionately very much larger than those observed in bulbs. It follows that if a thermometer reads 0.1 deg. higher at one point of the scale than it did when calibrated it will also read 0.1 deg. higher at all other points of the scale. This statement applies almost without qualification to Centigrade thermometers not used above 400 deg. or Fahrenheit thermometers not used above 750 deg. but may not be strictly applicable to Centigrade thermometers used at relatively high temperatures such as 500 deg. or to Fahrenheit thermometers used at temperatures such as 900 deg. The above discussion applies especially to thermometers made of the glasses named in A.S.T.M. specifications. Some of the glasses suitable for temperatures as high as 600 C. or 1100 F. appear to be subject to much smaller changes in volume.

The most convenient point for use in determining whether changes in the volume of the bulb have occurred is the ice point, although other points, such as the steam point, or a point in the range 20 to 30 C. (68 to 86 F.) may also be used. If a point in the room temperature range is used, comparison must be made with a suitable standardized thermometer having an ice point on its scale. This would involve a comparison of dissimilar thermometers, but in comparisons at room temperature, this is not a disadvantage.

It is for the reasons explained in this section that thermometer certificates of the National Bureau of Standards carry the proviso that the corrections are applicable provided the ice point (or other point) reading, under stated conditions is as shown on the certificate. If the ice point reading is higher (or lower) all other readings will be higher (or lower) to the same extent. Only if the thermometer is not graduated above 150 C. (or 300 F.) and corrections are given to not better than the nearest 0.1 C. (or 0.2 F.) may it be assumed that the changes in the volume of the bulb will be inappreciable, and in such case thermometers may be certified even though no convenient means for determining changes in bulb volume has been provided.

In addition to the more or less permanent changes in bulb volume described above, there are temporary changes, resulting from heating, which may have to be taken into account when using thermometers graduated in 0.2 or 0.1-deg. intervals. If these are read only to the nearest 0.1 deg. the temporary changes need not be taken into account, but if they are read to 0.1 division, that is to 0.02 or 0.01 deg., the temporary changes may be larger than the error in reading. If a thermometer which has been kept for several days at room temperature is heated to a higher temperature, the bulb will, within a very few minutes, assume the volume corresponding to the higher temperature. If the bulb is then cooled back to the original temperature, it does not at once return to the original volume, but remains slightly larger, with a consequent "depression" of the reading. For the glass of which most A.S.T.M. thermometers are made, the depression amounts to somewhat less than 0.01 C. for each 10 deg. that the bulb is heated above the original temperature. For example, if a thermometer, which has been for several days at room temperature, is heated to 80 C., it will read about 0.06 deg. lower at 20 C., about 0.03 deg. lower at 50 C., and about 0.01 deg. lower at 70 C., than it would have if it had been used successively at 20, 50, and 70 C., without previous heating to 80 C. These temporary depressions disappear almost completely within a few days. Since thermometers are tested beginning at the lowest temperature and working up, the error resulting from the temporary depression can be avoided by using them in the same way, that is, measuring the lowest temperature to be determined first, and the higher temperatures in succession. The depression is fairly regular if the thermometer is not heated above 150 C., but cannot be predicted if the thermometer is heated to higher temperatures. However, in the routine testing above 150 C. of A.S.T.M. thermometers, this "depression" error need not be taken into consideration.

Standard Thermometers for Use in Testing:

As already stated, the most suitable standards for use in testing of the kind contemplated in this discussion will be those made to exactly the same specifications as the thermometers to be tested. It would be merely good judgment if in selecting working standards, those conforming as nearly as possible to the average dimensional requirements were chosen, avoiding those which were close to the limit in any dimension. A number of such thermometers could be selected from manufacturers stocks and perhaps marked "Working Standard." These working standards should be tested by a well-equipped testing laboratory, such as that of the National Bureau of Standards. Due attention should be given to the conditions stated in the certificate issued with the instrument, under which the certified corrections are applicable. In particular, the readings at the ice, steam, or other point specified in the certificate should be determined, so that the effects of any changes in bulb volume may be taken into account. Experience in the use of the thermometer is a good guide for determining how frequently the reference point should be redetermined.

When similar thermometers are compared, many of the precautions which have to be taken when dissimilar thermometers are compared can be disregarded. For example, if two similar partial immersion thermometers are to be compared, and both are immersed a few inches too deep, both will read high, and the comparison will yield the same result that would have been obtained if both had been immersed only to the immersion mark. Similarly in comparing two similar total immersion thermometers the correct result will be obtained even if a few inches of the mercury columns are emergent from the bath. The principal requirements of a comparison bath for testing similar thermometers is therefore that it bring the bulbs to the same temperature, that the stem temperatures be substantially the same for the several thermometers to be compared, and that the temperature be either constant or changing slowly, preferably rising.

Testing Equipment:

The principal item of testing equipment is a bath or other means of bringing the thermometers to be compared to a temperature which can be controlled sufficiently well for the purpose of the tests. The types of baths which are most useful are the ice bath, stirred liquid baths, vapor baths and in some instances, electrically heated metal block comparators.

Ice Baths.—Because of the changes in bulb volume described previously, the ice bath, which provides a convenient means of determining the amount of such changes, is one of the most important pieces of equipment for a thermometer-testing laboratory. The most convenient form of ice bath consists of a wide-mouth thermos bottle or Dewar flask, filled with a mixture of shaved ice and distilled water, or water obtained by melting of the ice. Other containers may be used, but are likely to be less convenient because of the more rapid melting of the ice. Any ice which is clear is probably sufficiently pure for the purpose and clear ice is readily obtainable. The ice may be shaved by means of a small plane, resembling a carpenter's plane, or other appropriate mechanism. There should be enough water in the mixture to make it soft or slushy, but not enough to cause the ice to float. Excess water which accumulates may be conveniently removed by means of a glass siphon, ending in a rubber tube with a pinch cock. Precautions should be taken to wash the ice and to avoid contaminating it in handling.

Liquid Baths.—For comparisons to be made at temperatures not differing much from room temperature, a bucket of water, stirred by hand with a good sized wooden paddle, is a very excellent piece of equipment, hardly to be surpassed, as concerns accuracy attainable, by the most elaborate mechanism.

However, if the temperature at which the thermometers are to be tested differs appreciably from room temperature, more elaborate equipment becomes necessary. For temperatures between 5 and 95 C. (41 and 203 F.), water is in general the most suitable liquid. For temperatures above 95 C. (203 F.), an oil, such as a light engine oil, is satisfactory. No ideal liquid for such purposes has yet been discovered. An oil, which is sold as engine oil, and which has the following characteristics, has been used for many years:

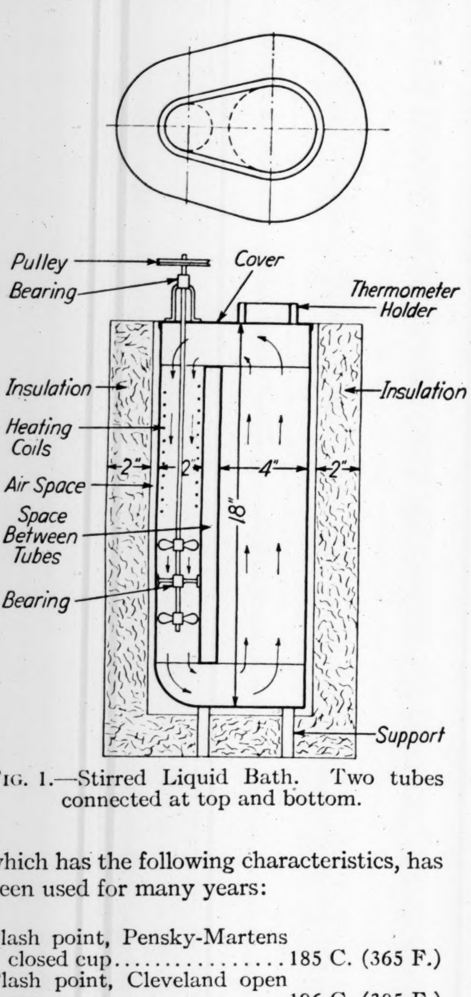
Pulley
Bearing
Cover
Thermometer Holder
Insulation
Insulation
Heating Coils
2"
2"
4"
2"
Air Space
Space Between Tubes
18"
Bearing
Support

FIG. 1.—Stirred Liquid Bath. Two tubes connected at top and bottom.

Flash point, Pensky-Martens closed cup	185 C. (365 F.)
Flash point, Cleveland open cup	196 C. (385 F.)
Fire point, Cleveland open cup	218 C. (425 F.)
Viscosity, Saybolt Universal at 210 F. (99 C.)	43 sec.

Qualities desired in a liquid to be used for this purpose are chemical inertness, stability, low volatility, high flash and fire points, or preferably, nonflammability, low viscosity at temperatures above 95 C. (203 F.), and freedom from properties which would make it unpleasant to use or handle. The oil described above is somewhat too viscous to stir well at 100 C. (212 F.) but becomes sufficiently fluid at higher temperatures. It has been used regularly at temperatures up to 600 F. (315 C.), although it gives off a considerable volume of vapor at temperatures above 400 F. (205 C.), and precautions against ignition, either communicated or spontaneous, must be taken when it is used above this temperature.

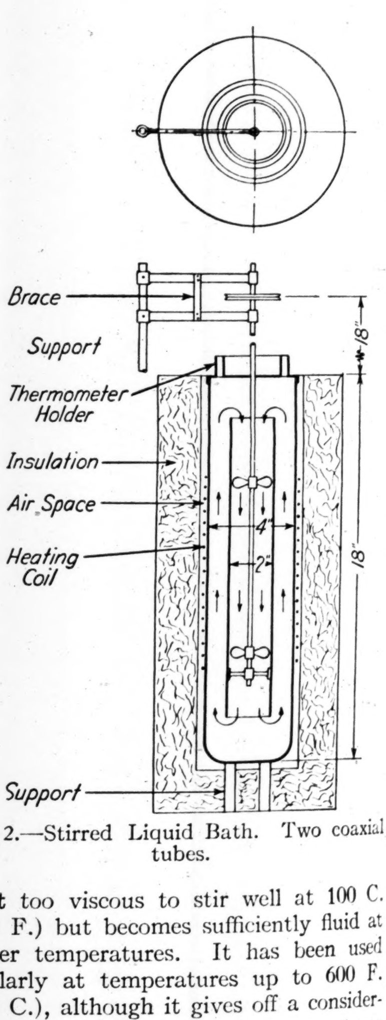
Brace
Support
Thermometer Holder
Insulation
Air Space
Heating Coil
4"
2"
18"
18"
Support

FIG. 2.—Stirred Liquid Bath. Two coaxial tubes.

For temperatures above 500 F. (260 C.), a heavier oil, having a flash point above 700 F. (370 C.), may be used up to and including 700 F. One oil of this kind which has been used successfully is described as "steam refined cylinder oil with flash point about 720 F. (380 C.), Cleveland open cup." This oil is not too viscous for good stirring at 500 F. (260 C.).

If an oil is used above its flash point, the container should, after use, be covered with a special cover having no openings since it has been observed that the oil, after being used at high temperatures, may ignite spontaneously after it has cooled considerably, if left uncovered, or partly covered.

If an oil is used at temperatures above 400 to 500 F. (205 to 260 C.), it gradually deteriorates, and must be renewed from time to time.

A stirred liquid bath consists essentially of a container of sufficient cross-section for the purpose, and of sufficient depth to permit immersing the thermometers as far as is necessary. In general, the diameter of the container should not be less than 3 in. For A.S.T.M. thermometers a depth of 12 to 18 in. should be sufficient. The stirrer should preferably be a motor-driven screw propeller, located in a separate tube somewhat larger than the propeller. This stirrer tube should have a cross-sectional area which need not be greater than one-quarter and should not be less than one-eighth the cross-sectional area of the bath itself. The stirrer tube may be located inside the main bath, either centrally or eccentrically, or may be outside the main bath, and connected to it by passages at top and bottom. The lower end of the stirrer tube should be above the bottom of the main bath by a distance about equal to or somewhat less than the diameter of the stirrer tube, and the upper end should be about the same distance below the level of the liquid. For a stirrer tube of the proportions suggested, and with a reasonably effective screw propeller, a speed of 400 to 600 r.p.m. should provide adequate stirring.

A type of bath consisting of two tubes with connecting passages at top and bottom is shown in Fig. 1. The heating coil is located in the stirrer tube. This type of bath is not suitable for use with a medium which becomes solid at room temperature. It has the advantage that the useful space is unobstructed at the top.

Another type of bath is shown in Fig. 2. Instead of the screw propellers shown, an impeller may be used below the lower tube. The impeller causes the liquid to flow upward in the annular space and to move downward in the central tube. A screen to prevent thermometers from being hit by the impeller should be provided.

These baths should preferably be provided with a cover, having openings as few as and as small as practicable. The cover may be arranged to carry a thermometer holder.

The level of the liquid should preferably be kept an inch or so below the top of the container, to avoid spilling or creeping of the liquid over the sides. Allowance must be made for expansion of the liquid as it is heated, most conveniently by means of an over-flow at a fixed level.

Electric heating is most convenient. Electric heaters may be built in a great variety of forms. For example, the heating wire or ribbon may be wrapped, over insulating material, on the outside of the main container. Again, the heating element, in the form of bare wire or ribbon, may be mounted inside the stirrer tube in such a position that the liquid first passes through the heating element, then through the propeller, which serves to promote mixing. In any case the heating element should not be in the space occupied by the thermometer bulbs, that is, it should either be wound on the outside of the container or located inside the tube containing the stirrer. In selecting a heating element, it is desirable to avoid one having heavy insulation, or other heat capacity, as this makes it more difficult to control the bath temperature. For the heating element the alloys ordinarily used for electric heating are satisfactory. When the bare resistor is immersed in water, an alloy of 60 per cent gold, 40 per cent palladium, or 90 per cent platinum, 10 per cent rhodium, whichever happens to be cheaper, is satisfactory provided alternating current is used for heating. When the alloy is used in the form of a thin ribbon, the cost of the amount needed is trifling.

For the sizes of baths shown in Fig. 1 or Fig. 2 it will be found advantageous to design the heating coil for an input of 1 to 2 kw. for rapid heating between test points. For example, if the supply voltage is 110, the heating coil may be made with a resistance between 6 and 12 ohms. For maintaining the very slowly rising temperature at the test points, rheostats in series may be used, or if the current is alternating, a transformer with variable secondary voltage. These are obtainable with a rating of 2 kva. and are made for line (input) voltages of either 115 or 230, with the secondary (output) voltage adjustable from 0 up to line voltage.

Insulation around the bath is advantageous both because it prevents heat loss and because it promotes temperature uniformity. For very temporary use, a few layers of asbestos felt wrapped around the container will serve. In a permanent installation it is best to put the insulation in a double-walled compartment, separate from the bath itself, so that the bath can be set into the insulating unit and removed when necessary. In this way, the oil, if oil is used, is less likely to get into the insulating material, and it is not necessary to unpack the insulation if repairs have to be made to the inner parts. As insulating material, ground cork may be used for temperatures below 100 C. and such materials as asbestos magnesia mixtures, diatomaceous earth, expanded vermiculite, rock wool or slag wool, etc., for temperatures at which cork would char. Asbestos alone is not a particularly good insulator, especially in the fabricated forms such as asbestos board, paper, etc. A thickness of 1 to 2 in. of insulation is sufficient for most purposes.

Some kind of holder must be provided for the thermometers, except perhaps in the case where two thermometers may be held with one hand while the readings are recorded with the other. The holders may be comparatively simple, or as elaborate as the taste and resources of the user will permit. In general, a holder contains a series of openings for the thermometers which are held in place by springs.

Low-Temperature Baths.—A low-temperature bath is most conveniently made by using a wide-mouth vacuum bottle or Dewar flask, preferably equipped with a motor-driven stirrer. As a bath liquid, a nonflammable mixture of approximately equal volumes of chloroform and carbon tetrachloride may be used. The mixture, when cold, will absorb moisture from the air and will gradually corrode metals left in it for long periods. The mixture should preferably be strained after use, while still cold, to remove ice and kept in a well-stoppered bottle. Instead of the nonflammable mixture, it is possible to use alcohol or gasoline, but their use introduces a hazard which it is better to avoid. The mixture is cooled by adding solid carbon dioxide (dry ice). After being cooled to the desired temperature, the rise in tem-

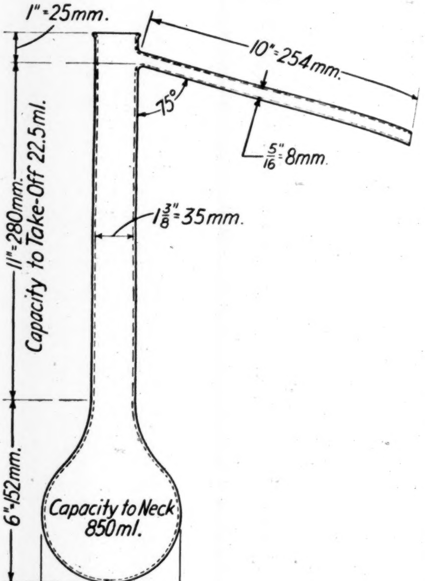

FIG. 3.—Pyrex Flask for Thermometer Calibration.

perature should be slow enough for the purpose of making tests, without any special means of control, if the insulating flask is a good one and the stirring is not too rapid. If the thermometers contain a liquid other than mercury, they should be cooled slowly and regularly and held at the low temperature for some time in order to promote drainage of the liquid in the capillary, and the capillary should be kept warm until after the bulb has been cooled.

Vapor Baths.—A convenient apparatus is shown in Fig. 3. The apparatus is made of Pyrex glass and the neck is long enough to permit calibration of any A.S.T.M. thermometer at total immersion.

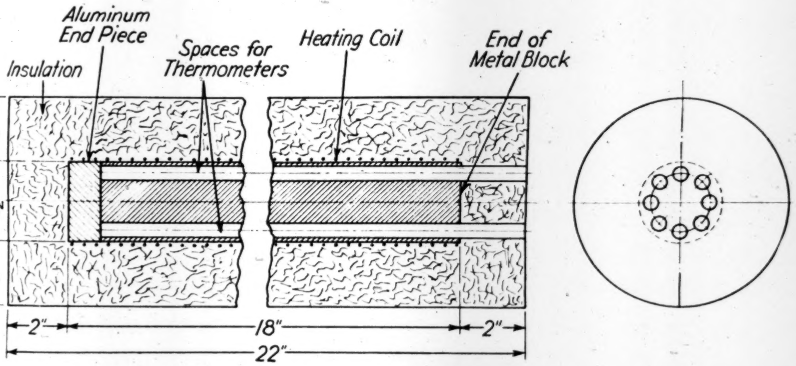

FIG. 4.—Metal Block Comparator.

The neck is wrapped from the bulb up to a short distance below the take-off, first with thin aluminum foil and then with two layers of asbestos paper.

From 100 to 200 g. of the bath substance is placed in the bulb and it is held in a stand over a bunsen burner. A small beaker is arranged to collect the condensed vapor at the end of the take-off tube.

A small amount of sand may be used in the bulb to prevent super-heating of the vapor by direct radiation.

The burner is adjusted so that the line of condensing vapor is just above the take-off and a few drops per minute of condensate come over through the side tube.

The thermometer under test together with a like standard is held in the flask so that the indicated temperature point is just in the vapor, thus giving the condition of total immersion, and when steady conditions are reached the readings are made on both thermometers. Partial-immersion thermometers should be immersed so that the immersion mark is about at the level of the take-off.

For routine work with, for example, an A.S.T.M. high-distillation thermometer, a set of four bulbs containing water, naphthalene, benzophenone and anthracene may be used. This gives, with the ice point, five points fairly well distributed over the scale and should permit identifying any serious error in pointing, graduation or resulting from seasoning. If a like standard thermometer is not available, approximate calibration temperatures (in Centigrade) at corrected barometric pressure, p, in millimeters of mercury, may be determined if pure materials are used as follows:

	DEG. CENT.
Water.	$100.0 + 0.037\ (p—760)$
Naphthalene.	$218.0 + 0.058\ (p—760)$
Benzophenone.	$305.9 + 0.063\ (p—760)$
Anthracene.	$339.9 + 0.066\ (p—760)$

Metal Block Comparators.—For testing thermometers above 700 F. and for conducting the permanency of range test,[1] an electrically heated metal block comparator may be used.

A comparator of this kind, shown in Fig. 4, consists of a cylinder of copper or aluminum 2 or 3 in. in diameter and 12 to

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[1] See p. 500.

18 in. long with a number of holes of suitable size for the thermometers, parallel to the axis. It is most easily made by casting aluminum around a set of brass tubes. One such comparator was made with 8 brass tubes, $\frac{7}{16}$-in. outside diameter, and 0.04-in. wall (No. 18 gage) spaced with their centers on a circle $1\frac{5}{8}$ in. in diameter. The casting was turned to an outside diameter of $2\frac{1}{2}$ in., and a 1-in. aluminum plate was fastened to one end with screws. A winding of resistance wire or ribbon over electrical insulation serves for heating. The winding should preferably be spaced somewhat more closely near the ends than at the middle of the cylinder. The whole is enclosed in heat insulating material which should have a thickness of about 2 in. with an equal thickness over the ends of the cylinder. It is convenient to use the cylinder with its axis horizontal.

The heating coil may be wound for an input of about 1 kw. for rapid heating. For use on a 110-v. circuit an appropriate resistance is about 12 ohms. The temperature control may be arranged as described for liquid baths.

Ordinarily the temperature will not be uniform along the length of such a cylinder, and if it is used, the bulbs of the thermometers should be at the same depth, and it may then be assumed that the mercury in the stems is substantially at the same average temperature. An accuracy of the order of 0.5 F. may be expected with apparatus of this type under favorable conditions.

Checking Dimensions:

If only a few thermometers are to be tested, specified lengths may be checked by use of a graduated scale, and diameters by use of a suitable caliper. If large numbers of thermometers are to be tested, the testing can be expedited by providing some simple special equipment.

A simple apparatus for checking distances consists of a board a little longer than the thermometer with a stop at each end. At suitable distances from the stops, lines are ruled on the board corresponding to the tolerances for the various specified dimensions. For example, if the specification requires that the distance to the 0 line from the bottom of the bulb shall be 90 to 100 mm., lines would be ruled on the board at distances of 90 and 100 mm. from one stop. When the end of the bulb is placed against the stop, it can be seen at once whether the 0 mark falls between the two lines. Other pairs of lines, corresponding to total length, bulb length, distance from top of stem to a specified graduation mark, etc., are ruled on the board or on a sheet of drawing paper cut to fit the board. A separate set of rulings would be required for a different specification.

For checking diameters of stems or bulbs a simple go and no-go gage may be made by drilling holes corresponding to the upper and lower limits specified for diameter, in a metal, hard rubber or bakelite plate. The dimensions of the holes in the metal plate may be more permanent, but the hard rubber or bakelite plate is less likely to cause breakage of a thermometer.

Any of the devices described may be made very inexpensively or the design may be elaborated as much as desired.

Test for Permanency of Range.—The specifications for A.S.T.M. thermometers graduated to 300 C. or 580 F. and above contain the following provision:

"Test for permanency of range: After being subjected to a temperature 10 C. or 20 F. below the maximum scale temperature for 24 hr., the accuracy shall be within the limit specified."

The wording is slightly different in some of the specifications but the alternative wordings are in effect equivalent to the one quoted. The purpose of the provision is to furnish a means for determining that the thermometer has been adequately annealed so that subsequent changes in bulb volume shall not be excessive. The test is omitted from specifications for thermometers not graduated above 300 C. or 580 F. because the test when applied to such thermometers provides no useful information. However, high-temperature thermometers, if not annealed, may show changes of 20 or 30 F. (10 or 15 C.) after a short period of use, while the indications of partly annealed thermometers may show smaller changes after a long period of service at high temperatures. The magnitude of the changes will depend on the length of service, the temperature of use and the effectiveness of the annealing procedure used by the manufacturer. Obviously, the user of the instrument cannot by any simple test determine just how completely a thermometer has been annealed, and as a matter of fact he is not primarily interested in this information. He wants to be assured that the indications will remain as nearly constant as can be expected for a well-made instrument. In making the test it is advisable to determine the reading of the thermometer at some reference point such as the ice or steam point before the period of heating and again at the end of the period. The specifications require only that the accuracy shall be within the limit specified after the test, but the additional information concerning the change in reading is very easily obtained, and may prove to be of value in judging the quality of the thermometer.

The test may be made conveniently by using the metal block comparator previously described. A simple electrically heated furnace consisting of a metal or porcelain or Pyrex glass tube having a diameter of 1 to 2 in., suitably wound with resistance wire or ribbon, to give a fairly uniform temperature throughout its length, and insulated may also be used for this purpose. Such a furnace will accommodate a larger number of thermometers than the metal block, and of course, if the temperature accidentally gets too high, may damage a larger number of thermometers. It is not necessary to heat the thermometers continuously for 24 hr. For example, the heating may be done in three periods of 8 hr. each. Where electric heating is used, the circuit voltage during the night may differ considerably from that during the day, so that it may not be advisable to allow the test to run overnight, in the absence of automatic temperature or voltage control. It is better, after the test for permanency of range, to allow the thermometers to remain for two or three days at room temperature, before making the tests for accuracy.

The test for permanency of range is important, and it is advisable to make it, when specified, before making the tests for accuracy. The test is especially important in those laboratories where it is not the custom to recheck the ice point or other reference points.

Choice of Test Points.—If the object of the test is merely to determine the quality of the thermometer in general, or to determine that the corrections do not exceed certain tolerances, the test points may be taken anywhere on the scale. If, on the other hand, the object of the test is to determine corrections which are to be used later, the test points should be somewhat uniformly spaced, and in general, in the way indicated in the specifications for the thermometer.

Unless the thermometer is to be used at only a few selected temperatures, it is not practicable to test it at all of the points at which it may be used. If the test points are not too far apart, corrections at intermediate points may properly be found by interpolation. In general, if the interpolations are to be dependable, the test points need not be less than 40 and should not be more than 100 divisions apart. Thus if a thermometer is graduated in 0.2-deg. intervals, it need not be tested at points less than 10 deg. apart, and the test points should not be more than 20 deg. apart, if interpolated corrections are to be reasonably reliable.

It appears to be a very commonly held opinion that if the corrections are small, the interpolation will be more reliable than if the corrections are large. For example, if a thermometer were found to be correct at 0 and 40 deg., it is usually assumed that it is probably also correct at 20 deg. If, however, the correction of 0 deg. were −2.0 deg. and that at 40 deg. were −2.8 deg., many users would feel that the interpolated correction of −2.4 deg. at 20 deg. was subject to a considerable uncertainty.

A little consideration will show that the interpolated correction 0.0 deg. at 20 deg. is just as uncertain as the interpolated correction of −2.4 deg. provided the thermometers were of equal quality in other respects.

Curious and sometimes distressing ideas about interpolation are occasionally encountered, ranging from the one to the effect that a thermometer which has been tested at 30 and 40 deg. may be wholly unreliable at 31 deg. unless tested at that point, to the other whose possessor blithely assumes that if a thermometer is tested and found correct at 0 and 400 deg., it is necessarily correct at all intermediate points. It is well to avoid both extremes.

Procedure in Testing.—In making a test, all thermometer readings should be recorded. If it is not worth while to record the readings, it is not worth while to make the test. In general, it is advisable to use two standards. The general procedure may be illustrated by a case in which four thermometers are to be compared with two standards.

The ice point or other reference points of all the thermometers should be determined first.

In determining the ice point, the thermometer is inserted into the mixture of ice and water in the ice bath, and read after the indication has become constant. It will usually be found that the meniscus tends to stick a little and that jarring the thermometer gently will induce a lower reading. If the jarring is too severe, the rebound may cause too high a reading.

For reference points in the room temperature range a bucket of water, stirred by hand with a wooden paddle, may be used, without any special elaboration. A motor-driven stirrer may be used.

If the reference point is the steam point, a vapor bath with water as the bath fluid may be used. The immersion in the steam should be that for which the thermometer is designed. In this case, the temperature of the steam may be determined from the pressure, necessitating the use of a barometer. The barometer readings should be corrected for the effect of temperature, and for the difference between the local value of *g* and the standard value. Account should also be taken of any difference of pressure existing between the point at which the thermometer bulb is located and the pressure at the barometer, unless both are on the same floor of the building. Having thus determined the pressure of the vapor, the temperature may be taken from a suitable table, such as those found in Smithsonian Physical Tables or Smithsonian Meteorological Tables. These tables also contain the data needed for correcting barometer readings. The temperature of the steam may also be determined, somewhat more conveniently, with a standardized thermometer, having both ice and steam points on the scale.

The thermometers should then be mounted in the testing bath, approximately to the depths for which they were designed, that is, total immersion thermometers should be immersed so that only enough of the mercury column projects above the bath for convenience in reading, and partial immersion thermometers should be immersed to the proper mark. As previously stated, a slight departure from the designated immersion is not important provided the thermometers are alike and equally immersed. In selecting the depth of immersion the location of the bulb is of more importance than the position of immersion marks. The bulbs of the thermometers to be compared should preferably be close together in the bath, and it should be remembered that the interior of a bath is, in general, more uniform in temperature than the parts near any boundary, in particular, that the region near the surface of a liquid bath may not have exactly the same temperature as the interior of the bath.

The thermometers should be arranged so that readings are made in the following order: Read first standard, read the four thermometers being tested, in order, read second standard, repeat reading of second standard, read the four thermometers being tested in reverse order, read first standard. Take the average of the two readings for each thermometer. If the temperature has been constant or changing uniformly and the readings have been made at equal time intervals, the average of the two readings of any thermometer should correspond to the same temperature as the average of the two readings of any other thermometer. Apply the corrections, including corrections for change of bulb volume, to the averaged readings of each standard and compute the temperature of the bath. The two standards should check within the accuracy desired. Having determined the temperature of the bath, the averages of the readings of the thermometers being tested may be compared with it, and the corrections calculated. At least two and preferably three or four such sets of readings should be made at each test point.

The means adopted for reading the thermometers should be at least as good as those employed in the regular use of the instruments. In some cases readings with the unaided eye will be satisfactory. Much better readings can be made with the aid of a magnifying glass or simple reading telescope. A reading telescope magnifying about 10 times and movable vertically by means of a rack and pinion, together with a rotatable holder by means of which the thermometers may be brought successively into the field of view of the telescope, provides a very convenient and desirable arrangement where a large number of thermometers are to be tested.

In all cases, precautions should be taken to insure that the line of sight is perpendicular to the thermometer to avoid errors due to parallax. If the illumination is suitable, the reflections of the graduation marks in the mercury column can be seen, and then if the mark below the mercury meniscus covers its own reflection, the line of sight is known to be perpendicular to the thermometer.

Except when using a vapor bath, it is preferable to have the temperature rising slowly when readings are being made, since mercury in glass thermometers can be most accurately compared under these conditions. A suitable rate of rise is from $\frac{1}{10}$ to $\frac{1}{3}$ of a smallest scale division per minute, so that the mercury meniscus will rise one scale division in from 3 to 10 min.

In using a vapor bath, the operator ordinarily has no control over the temperature of test, nor of the rate of change of temperature, and must use the bath under the prevailing conditions. The temperature will be very nearly constant under usual conditions.

If the temperature of the bath is stationary or falling slowly, the mercury meniscus may tend to stick or move irregularly. In such cases a small buzzer operated by a dry cell may be attached to the thermometer. The vibration produced by operation of the buzzer is usually effective in preventing sticking of the meniscus.

In reading thermometers, account must be taken of the fact that the lines are of appreciable width. The best practice is to consider the position of the line as defined by its middle part. In some thermometers the lines are so wide that the edge of the line is more than a tenth of a division away from the middle. However, it is permissible to read the thermometer as though the position of the line were defined by its upper or by its lower edge. Provided this is done consistently throughout, the results should be the same as though the middle of the line were used, except in the case of thermometers having no reference point, since in this case the position of the line was presumably taken as the position of the middle part when the thermometer was standardized.

Accuracy:

The word "accuracy" as used in connection with thermometers might well be supposed to refer to the accuracy attainable in the use of an instrument. For example, a particular thermometer might be said to be accurate to 0.1 deg. if, when properly used (which would include application of calibration corrections), the results obtained with it would not be in error by more than 0.1 deg. On this basis, it would make no difference in the accuracy of the thermometer whether the calibration corrections were very small or very large. The word accuracy is not used in

Table I.—Tolerances for Mercurial Total-Immersion Laboratory Thermometers.

Centigrade Thermometers				Fahrenheit Thermometers			
Temperature Range, deg.	Graduation Interval, deg.	Tolerance, deg.	Accuracy, deg.	Temperature Range, deg.	Graduation Interval, deg.	Tolerance, deg.	Accuracy, deg.
Thermometers for Low Temperatures				**Thermometers for Low Temperatures**			
−35 to 0	1 or 0.5	0.5	0.1 to 0.2	−35 to 32	1 or 0.5	1	0.1 to 0.2
−35 to 0	0.2	0.4	0.02 to 0.5	−35 to 32	0.2	0.5	0.05
Thermometers Not Graduated Above 150 C.				**Thermometers Not Graduated Above 300 F.**			
0 up to 150	1 or 0.5	0.5	0.1 to 0.2	32 up to 300	2	1	0.2 to 0.5
0 up to 150	0.2	0.4	0.02 to 0.05	32 up to 300	1 or 0.5	1	0.1 to 0.2
0 up to 100	0.1	0.3	0.01 to 0.03	32 up to 212	0.2 or 0.1	0.5	0.02 to 0.05
Thermometers Not Graduated Above 300 C.				**Thermometers Not Graduated Above 600 F.**			
0 up to 100	1 or 0.5	0.5	0.1 to 0.2	32 up to 212	2 or 1	1	0.2 to 0.5
Above 100 up to 300		1.0	0.2 to 0.3	Above 212 up to 600	......	2	0.5
0 up to 100	0.2	0.4	0.02 to 0.05				
Above 100 up to 200		0.5	0.05 to 0.1				
Thermometers Graduated Above 300 C.				**Thermometers Graduated Above 600 F.**			
0 up to 300	2	2	0.2 to 0.5	32 up to 600	5	4	0.5 to 1.0
Above 300 up to 500		4	0.5 to 1.0	Above 600 up to 950		7	1 to 2
0 up to 300	1 or 0.5	2	0.1 to 0.5	32 up to 600	2 or 1	3	0.2 to 1.0
Above 300 up to 500		4	0.2 to 0.5	Above 600 up to 950		6	0.5 to 1.0

Table II.—Tolerances for Mercurial Partial-Immersion Laboratory Thermometers.

Centigrade Thermometers				Fahrenheit Thermometers			
Temperature Range, deg.	Graduation Interval, deg.	Tolerance, deg.	Accuracy, deg.	Temperature Range, deg.	Graduation Interval, deg.	Tolerance, deg.	Accuracy, deg.
Thermometers for Low Temperatures				**Thermometers for Low Temperatures**			
−35 to 0	1 or 0.5	0.5	0.2 to 0.3	−35 to 32	1	1	0.3 to 0.5
Thermometers Not Graduated Above 150 C.				**Thermometers Not Graduated Above 300 F.**			
0 up to 150	1 or 0.5	1.0	0.1 to 0.5	32 up to 300	2 or 1	2	0.2 to 1.0
Thermometers Not Graduated Above 300 C.				**Thermometers Not Graduated Above 600 F.**			
0 up to 100	1	1.0	0.1 to 0.3	32 up to 212	2 or 1	2	0.2 to 0.5
Above 100 up to 300	1	1.5	0.5 to 1.0	Above 212 up to 600	2 or 1	3	1 to 2
Thermometers Graduated Above 300 C.				**Thermometers Graduated Above 600 F.**			
0 up to 300	2 or 1	2.5	0.5 to 1	32 up to 600	5 or 2	5.0	1 to 2
Above 300 up to 500		5	1 to 2	Above 600 up to 950		10	2 to 3

this sense, however, in the A.S.T.M. specifications, nor in the thermometer trade generally. In the thermometer trade "accuracy" means "scale error."

The accuracy usually attainable with various types of thermometers at various temperatures is indicated in Tables I and II, abbreviated from National Bureau of Standards *Circular No. 8*, fourth edition. If a thermometer submitted to the National Bureau of Standards is found to have corrections larger than the tolerances, it receives a report but is denied a certificate. The "tolerances" in these tables correspond to the A.S.T.M. "scale error." If an A.S.T.M. thermometer is tested merely to determine that it complies with the specifications, and is used without applying calibration corrections, the accuracy attainable with it in this way is also no better than the permissible scale error. It will be noted that in general the N.B.S. tolerances are considerably more liberal than the A.S.T.M. permissible scale errors, and that the N.B.S. "accuracy," meaning accuracy to be expected of the thermometer if properly used, is considerably better than the A.S.T.M. permissible scale error. The reasons for these differences are very instructive.

The N.B.S. tolerances are based on what may reasonably be expected with good manufacturing practice, and the accuracy given in the tables is determined chiefly by the properties of the thermometer itself. In order to attain this accuracy, the thermometer should, in general, be read to the nearest 0.1 division, calibration corrections should be applied, etc.

It is apparent that the A.S.T.M. requirements are based on a different point of view. In each test, the accuracy desired in the final result is determined upon by the committee in charge of the test. The specification for the thermometer is then written to require that the permissible scale error shall not exceed certain limits, which are smaller than, or at most equal to, the permissible error in the test. In many cases it appears that it is expected that the thermometer readings will be made to the nearest half, or possibly the nearest quarter, of a division. The A.S.T.M. specifications place upon the manufacturer the responsibility of making thermometers so nearly correct that the user may take their readings at face value. Obviously, a specification of this kind will differ in important respects from one based on the point of view which led to the values given in Tables I and II. In general, the A.S.T.M. specifications call for a better thermometer to attain somewhat less reliable results than could be obtained by applying corrections.

In many of the A.S.T.M. tests, accuracy as such is of no importance, but reproducibility is greatly desired. For example, in the distillation tests in which total-immersion thermometers are used at partial immersion, the thermometer readings may differ by many degrees from the temperature of the bulb. In these tests, the expression "thermometer reading" is used instead of the word "temperature," since the actual temperature in such tests is of no interest. The purpose of the specification is to provide a method which will yield comparable results in the hands of all users.

REPORT OF COMMITTEE E-2
ON
SPECTROGRAPHIC ANALYSIS

Committee E-2 on Spectrographic Analysis has held no meeting since that held during the annual meeting of the Society in New York City in 1937. At that time certain revisions of the Tentative Methods of Quantitative Spectrochemical Analysis of High Grade Pig Lead for Copper, Bismuth, Silver and Nickel (E 25 – 35 T), and of Quantitative Spectrochemical Analysis of Zinc Alloy Die Castings for Minor Constituents and Impurities (E 27 – 35 T) were approved by unanimous vote and referred to letter ballot of the committee. On August 26, 1937, the committee presented[1] the revisions to the Society through Committee E-10 on Standards. The recommendations were accepted by Committee E-10 and the methods as revised were issued as a separate reprint.[2]

Subcommittee III on Quantitative Methods and Applications and Subcommittee V on Standards and Pure Materials met on March 11, 1938, during the spring group meetings in Rochester, N. Y., but due to the small attendance, no formal action was taken by either on matters to be reported to the main committee.

The Tentative Method of Quantitative Spectrochemical Analysis of Zinc for Lead, Iron, and Cadmium (E 26 – 35 T) has now stood without revision for three years. Due to the delay in the preparation of this report there was insufficient time for submitting to letter ballot of the committee the question of adopting this method as standard. Although no action on the method can be taken at this meeting, it will be brought up for consideration next year.

The by-laws of Committee E-2 were approved at the June, 1937, meeting and were subsequently referred to letter ballot of the committee with the following results: Of a total membership of 44, 34 members returned their ballots, all of whom voted affirmatively.

The committee is pleased to report that the manuscript for an "Index to the Literature on Spectrochemical Analysis (1920–1937)," has been completed by William F. Meggers and Bourdon F. Scribner of the National Bureau of Standards. As mentioned in last year's report, this Index has been offered by the compilers for publication by the A.S.T.M. Publication has been approved by Committee E-6 on Papers and Publications, provided that it seems clear that there will be sufficient demand to underwrite the expense. This question has been considered by the members of the Advisory Committee of Committee E-2 and it is their unanimous opinion that there will be sufficient demand to justify an edition of 1000 copies. In its final form, the Index consists of a brief introduction, 930 literature citations and a detailed index. It covers all important contributions to the literature of spectrochemical analysis since the first development of methods of sufficient accuracy and reliability to serve as a basis for the commercial inspection of materials.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee E-2 reported the following results of the letter ballot vote: Of a total membership of 44, 30 members returned their ballots, of whom 26 voted affirmatively, 0 negatively, and 4 marked their ballots "not voting."

[2] 1937 Supplement to A.S.T.M. Methods of Chemical Analysis of Metals, 1936.

The Division of Chemistry and Chemical Technology of the National Research Council has approved the formation of a Committee on Spectroscopy as Applied to Chemistry if it is the feeling of Committee E-2 that such a committee would not overlap the work of the A.S.T.M. A letter addressed to chairman H. V. Churchill by Herbert R. Moody, chairman of the N.R.C. Division, asked that he be informed of the opinion of Committee E-2. He brought out the fact that there are fields of application of spectroscopy to chemistry that come within the province of the National Research Council, but which are outside that of the A.S.T.M. He suggested the possibility of cooperation between the two organizations on common problems.

Mr. Churchill referred this matter to the members of the E-2 Advisory Committee. It was their opinion, expressed without dissent, that the committee of the National Research Council need in no way interfere with the work of the A.S.T.M., but would rather supplement it, extending the application of spectroscopy to many fields not concerned with engineering materials and making available to Committee E-2 developments that could be applied to its work. Wallace R. Brode of Ohio State University, a member of Committee E-2, has been appointed chairman of the National Research Council Committee and has consulted with members of Committee E-2 in his selection of men to serve with him.

The chairman has appointed the following members to serve as representatives of Committee E-2 on other standing committees:

K. J. Mackenzie on Committee E-1 on Methods of Testing,

T. A. Wright on Committee E-3 on Chemical Analysis of Metals, and

M. L. Fuller on Committee E-8 on Nomenclature and Definitions.

A. W. Kenney was appointed from Committee E-2 as one of the representatives of the A.S.T.M. on the Inter-Society Color Council.

The election of officers for the ensuing term of two years resulted in the selection of the following:

Chairman, H. V. Churchill.
Vice-Chairman, T. A. Wright.
Secretary, B. F. Scribner.

This report has been submitted to letter ballot of the committee which consists of 47 voting members; 37 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. V. CHURCHILL,
Chairman.

C. C. NITCHIE,
Secretary.

REPORT OF COMMITTEE E-3
ON
CHEMICAL ANALYSIS OF METALS

This report of Committee E-3 on Chemical Analysis of Metals is essentially one of progress in its program of developing methods for the sampling and chemical analysis of metals. This committee is still comparatively young, having been organized in 1935, but now contains a personnel of 59 members. It is organized in four divisions, with nine subcommittees.

The committee held a meeting on June 30, 1937, in New York City, and eight subcommittee meetings.

Division A on Ferrous Metals (G. E. F. Lundell, chairman) has completed an extensive revision of the Tentative Methods of Chemical Analysis of Ferro-Alloys (A 104 – 36 T) and will submit the new methods to the Society this year through Committee E-10 on Standards.[1] Subcommittees of this division are also working on methods for the determination of aluminum, columbium, tantalum, tin, arsenic, selenium, and lead.

Division B on Non-Ferrous Metals (R. P. Nevers, chairman) has been actively engaged in developing methods for the analysis of copper- and lead-base alloys. It is hoped that this work can be completed within the next year. Subcommittees B-3 and B-4 of this division are likewise working on methods of analysis for aluminum and zinc alloys.

Division C on Sampling (T. A. Wright, chairman) has completed its organization, forming four subcommittees as follows:

- Subcommittee C-1 on Basic Forms—Ingot, Pig, Slabs, Lump, etc. (C. B. Francis, chairman),
- Subcommittee C-2 on Cast Metals (G. H. Starmann, chairman),
- Subcommittee C-3 on Mechanically Worked Metals (F. M. Barry, chairman), and
- Subcommittee C-4 on Duplex, Powdered, Cathode, and Other Special Forms (M. S. Gerhard, chairman).

Subcommittee C-1 is revising the Tentative Methods of Sampling Ferro-Alloys (A 103 – 36 T) and may possibly complete the work in time to submit the new methods to the Society this year.

Division D on General Analytical Methods (B. L. Clarke, chairman) has completed its organization and is now ready to undertake such investigations as are referred to this division.

The election of officers for the ensuing term of two years resulted in the re-election of the present incumbents.

This report has been submitted to letter ballot of the committee which consists of 59 members; 41 members returned their ballots, of whom 36 have voted affirmatively, and 0 negatively.

Respectfully submitted on behalf of the committee,

G. E. F. Lundell,
Chairman.

H. A. Bright,
Secretary.

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[1] See Editorial Note, below.

Editorial Note

Subsequent to the annual meeting Committee E-3 on Chemical Analysis of Metals presented to the Society on August 25, 1938, through Committee E-10 on Standards a revision of the Tentative Methods of Chemical Analysis of Ferro-Alloys (A 104 – 36 T) in the form of new tentative methods. The revision was accepted by Committee E-10 and the new methods appear in the 1938 Supplement to A.S.T.M. Methods of Chemical Analysis of Metals, issued as a separate reprint.

REPORT OF COMMITTEE E-4
ON
METALLOGRAPHY

A meeting of Committee E-4 on Metallography was held during the annual meeting of the Society in New York City on June 30, 1937. The important activities of the committee since the last report have been the completion of the by-laws, the work on plastics for specimen mounting, the study of the polarizing microscope for problems of metallography, and the revision of the standard grain size chart for classification of steels. In the field of X-ray methods, a separate standing committee on radiography has been organized, designated Committee E-7 on Radiographic Testing; Subcommittee VI of Committee E-4 will therefore be concerned chiefly with problems of X-ray diffraction.

Committee E-4 reports a net gain during the year of 1 member, making a total membership of 50.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Selection and Preparation of Samples (E. H. Dix, Jr., chairman).—During the past year, the activities of this subcommittee have been concerned principally with efforts to secure a reliable, continuing source of "kitten's ear" broadcloth or the equivalent for metallographic polishing. Several different materials have been investigated, with the conclusion that at least one of them would be satisfactory. Pending arrangements for regular commercial distribution of this material, a cooperative purchase of a limited quantity by members of the Society was arranged and carried to a successful conclusion with the help of Society headquarters.

In view of the increasing use of plastics for mounting metallographic specimens, it was felt desirable to make available an authoritative summary of the present status of these materials. Since this could best be handled as an individually contributed paper, sponsored by the subcommittee, the resulting paper by L. L. Wyman, entitled "The Plastics for Mounting of Metallographic Samples," appears in an Appendix to this report.

Subcommittee IV on Photography (L. V. Foster, chairman).—This subcommittee met in Rochester, N. Y., on March 9, 1938, and the discussion centered on the usefulness of microscopic examination of metallic materials under polarized light. Several very definite applications of great value were mentioned. Particular reference was given to the identification of non-metallic inclusions in both ferrous and non-ferrous alloys and the grain orientation in martensitic and austenitic structures. In accordance with the request of Committee E-4, a paper on "The Examination of Materials in Polarized Light,"[1] by L. V. Foster and J. E. Wilson, will be presented at this annual meeting of the Society. The chairman desires to acknowledge the helpful suggestions and assistance given by the subcommittee and others in the preparation of this paper.

Subcommittee VI on X-ray Methods (W. L. Fink, chairman).—In line with the proposal of Committee E-4 at the last annual meeting, a separate standing committee on Radiographic Testing has been formed. As a result, Subcommittee VI, of Committee E-4, on X-ray Methods was reorganized under the chairmanship of W. L. Fink. Its activities will be concerned chiefly with the development of X-ray diffraction methods in metallography and the applications of these methods to practical problems.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 315 (1938).

The joint conferences suggested by Subcommittee VI, which are sponsored by the American Institute of Physics at the invitation of representatives from the American Society for Metals, the American Institute of Mining and Metallurgical Engineers and the A.S.T.M., have been very successful in stimulating fundamental discussion and exchange of ideas concerning metals. They are known as Round-Table Discussions on the Physical Basis of Metallic Properties. Two such meetings are planned each year.

Subcommittee VII on Recommended Practice for Dilatometric Analysis (L. L. Wyman, chairman).—The organization of this subcommittee was discussed at the last meeting of Committee E-4 and L. L. Wyman was appointed as chairman. A questionnaire on the subject has been prepared and circulated to a wide list of investigators. It is hoped that by this means a consensus of opinion may be obtained on the various phases of the subject, and that a definite method of procedure can be established.

Subcommittee VIII on Grain Size (M. A. Grossman, chairman).—The subcommittee has continued the study of the Standard Grain Size Chart for Classification of Steels (E 19 – 33)[1] and has completed a revision which meets many of the objections that have been raised. This revision has been considered and approved subject to the required letter ballot.

A special subcommittee appointed to draw up by-laws for Committee E-4 reported at the June, 1937, meeting and the by-laws were accepted with several minor changes. It was voted to submit them to a letter ballot of the committee when these changes were completed. The result of this ballot is as follows: Out of 50 members, 48 members returned their ballots, all of whom voted affirmatively.

The election of officers for the ensuing term of two years resulted in the selection of L. L. Wyman as chairman and the re-election of the present vice-chairman and secretary.

This report has been submitted to letter ballot of the committee, which consists of 50 members; 48 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. T. NORTON,
Chairman.

J. J. BOWMAN,
Secretary.

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[1] See Editorial Note below.

EDITORIAL NOTE

Subsequent to the annual meeting, Committee E-4 on Metallography presented to the Society on August 25, 1938, through Committee E-10 on Standards a proposed tentative revision of the Standard Grain Size Chart for Classification of Steels (E 19 – 33) in the form of a new tentative standard. This recommendation was accepted by Committee E-10 and the new grain size chart appears on p. 1296.

APPENDIX

THE PLASTICS FOR MOUNTING OF METALLOGRAPHIC SAMPLES

By L. L. Wyman[1]

The problem of a suitable mounting medium for samples is one with which the metallographist has long been faced and, until the comparatively recent application of plastics to this work, no generally useful material was available.

General Requirements

The requirements for a suitable mounting medium are many, one of the foremost of which concerns the chemical activity of the material.

The use of chemicals for etching, in order to reveal the structures of metals, is a necessary step in metallographic procedure. The range of materials employed varies from strong acids to strong bases, individually or mixed, and frequently involves the use of organic solvents.

The ideal mounting material should accordingly be impervious to any chemical attack, and should not interfere with the etching of the sample either by being attacked itself or hindering the proper attack of the etchant on the sample, and it should be permanent.

Another important requirement is that the mounting material be able to form readily around a sample of almost any shape, with almost perfect adherence and, at the same time, be able to flow into minute fissures and cracks in the sample. If the mounting medium does not do this, there is invariably trouble due to polishing materials and etchants being caught in the openings and later spoiling samples and equipment. In addition, improper bonding between sample and mounting materials tends to cause a rounding over of the sample edges during the polishing operation.

The mounting material should work down at the same rate as the sample in order that the latter may be completely supported at all times, and accordingly the polishing properties are important. This is not necessarily a matter of physical hardness alone, although the latter may be a fair criterion by which to judge the material.

The mounting material should be able to withstand some physical abuse and rough handling which might accidentally occur during the polishing operations.

The convenience of use is of course important in that the process of mounting the sample should neither take too long nor involve the use of elaborate and expensive equipment and materials.

In general, it may be said that modern plastic materials are quite suitable, and that most of the above requirements are met by many of these materials. There are, however, disadvantages which are oftentimes overlooked in the desire to obtain an apparently more favorable property.

Available Materials

The plastic materials now available may be divided into two classes: the thermoplastic resins which are formed by heat, or heat and pressure, without undergoing a chemical change, and the thermosetting resins in which the final chemical change or "setting-up" takes place during the forming process under the influence of heat and pressure.

There is a fundamental difference between these two types of plastics that has practical significance in the application of these materials to the mounting of metallographic samples. The thermoplastic resins, as stated above, undergo no change (other than the physical) during the forming process, and a repetition of the same process is possible. Whenever the temperature of these materials reaches the softening point, they will flow.

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[1] Research Laboratory, General Electric Co., Schenectady, N. Y.

With the thermosetting plastics an entirely different situation prevails for, when these materials are once "set-up" during the molding process, they are converted into an infusible product, the form of which cannot be altered until it has reached a sufficiently high temperature actually to char the resin.

This difference between the two types of plastics is of importance to the metallographist because the grinding and polishing operations produce heat which if the mounting is fusible, causes excessive flow of the mounting material which not only removes support from around the sample, but may allow it to shift. Furthermore, there is the tendency to smear over the sample and to clog the polishing papers rapidly.

The thermosetting resins are mostly of the phenol-aldehyde, phenol-furfural, urea-aldehyde, or alcohol-acid types, and, in most applications, are usually used in conjunction with some kind of filler material such as wood flour, asbestos, fibers or cloth, etc., to give the required strength. The first applications of plastics to metallographic mounting used materials of the phenol-aldehyde type with a filler.

The thermoplastic resins cover the range from the polystyrenes and the acrylates to the nitrate and acetate derivatives of cellulose. The recent trend in the use of mounting media seems to be toward the use of the acrylates because of their transparency.

Due to the fact that most of the thermosetting plastics utilize a filler, they are of necessity opaque, while the thermoplastic materials may be varied from transparent to opaque.

Because of the difference between the two types of plastics mentioned above, the method of manipulation is not the same. Both types of resins are molded at temperatures in the region of 125 to 150 C., and at comparable time and pressures. The thermosetting resins can be removed from the molds as soon as sufficient time and temperature have been given to accomplish the setting-up after the material has been forced into place by the pressure. The thermoplastics, on the other hand, require a cooling cycle down to 75 to 80 C. to bring the resin below its softening or flow temperature before it can be removed from the mold, thus involving the cooling operation and equipment as well as the reheating of the mold. This additional operation is both inconvenient and time consuming.

Most of the thermo-plastic resins have some cold flow while the thermosetting resins do not.

From the standpoint of hardness, Brinell tests on sample mounts, using a 10-mm. ball and 500-kg. load, show the following:

MATERIAL	HARDNESS	
Thermoplastic Type		
Polystyrene I	19	
Polystyrene II	22	Comparable to annealed aluminum
Methyl methacrylate:		
Soft	17–20	
Hard	27	Comparable to annealed copper
Thermosetting Type		
Aniline formaldehyde	30	
Phenol-formaldehyde plus wood flour	42	Comparable to semi-hard copper

CHEMICAL PROPERTIES

From the standpoint of the chemical properties of these plastic materials, it is found that the thermosetting resins are decomposed by strong oxidizing acids and by strong alkalies, but are resistant to strong reducing acids, organic acids, weak alkalies and organic solvents.

The thermoplastic resins may be somewhat attacked by the strong acids and alkalies. They are resistant to the weak acids and alkalies, but are usually very soluble in organic solvents.

There is little, if any, choice between the two types of materials from the standpoint of their ability adequately to be formed around the sample and to flow into small cracks and irregularities.

POLISHING CHARACTERISTICS

Results of polishing experiments which have been made on the several materials, the hardnesses of which were noted above, show that the hardness values may be considered a measure of the rapidity with which the mounting material will wear away during grinding and polishing, except in the instance of the aniline-formaldehyde.

The phenol-formaldehyde plastic with the wood flour filler is hard and its polishing behavior is in line with the softer materials, but the aniline formaldehyde plastic, which on hardness test is not much better than some of the softer materials, actually wears away less than does the phenolic product.

Of the above materials, the aniline formaldehyde product is definitely the best so far as the polishing behavior is concerned. It seems to have a high resistance to wearing away, is quite hard, dense, and is sufficiently strong. This aniline compound is reputedly harder than the phenolic base material in so far as the resins themselves are concerned. One important factor in the utilization lies in the fact that the former more readily can be used without a filler, which evidently improves the polishing properties.

It is sometimes advisable, in order to minimize the tendency for the edges of samples to round off, particularly with the softer mounting materials, to place a ring of a somewhat harder material around the sample when it is mounted.

TRANSPARENT MOUNTING

The present wide use of the transparent acrylates seems to be founded upon the fact that the metallographist can readily see and identify the sample. The use of a transparent mounting is justified in instances where it is necessary to grind and polish to a very definite place on the sample, but which is not the case in the majority of instances.

The rather dubious advantage of transparency is more than offset by the additional time and equipment necessary for best molding practice, the softness of the material, and the fact that the transparent materials are thermoplastic and therefore susceptible to rapid flow under polishing.

The thermosetting plastics have the one disadvantage of being opaque, but they possess superior properties in nearly every other respect, this being particularly true of the aniline formaldehyde product.

CASTING RESINS

The metallographist sometimes has samples which, due to their physical shape or nature, cannot withstand the pressure of molding without distorting or bending. There are plastic mountings which can be used for such materials if time is not important. Many of the thermoplastic resins can be obtained as casting resins, and there are other materials which are purely casting resins. These materials are cast into the mold and kept warm until the solvents have evaporated, leaving a product comparable to the molded product. The disadvantage lies in the fact that it usually takes a great many hours to accomplish this end.

EQUIPMENT REQUIRED

The equipment necessary for the use of plastics for metallographic mounting consists of a suitable press with or without heated platens, the heating being optional for electric or steam heat. Most of the commercially available presses of a size suitable for this work are powered by the conventional type of hydraulic jack such as used for automobiles, and require pumping up. However, where high-pressure water lines are available, the jack may readily be converted into a true press.

A suitable mold is necessary, and these, too, can be purchased for molding certain samples. Where it is necessary to have samples of definite shape to fit automatic polishing machines it is probable that the mold would have to be specially made.

In addition to the mold it is necessary to have a furnace jacket to heat it and, where thermoplastics are used, a suitable cooling jacket should be available to speed up the cooling necessary before the sample can be removed from the mold.

Where the facilities are available, it would seem that it would be preferable for the metallographist to adopt commercial molding practice by using a press having heated platens, and a mold which is cored for heating, both utilizing steam heat. This is particularly true for those who wish to use the thermoplastic resins, for by using T connections, either steam or water can be run through the platens and mold shell, thus increasing the speed of operation, and simplifying the mounting operation.

Thermoplastics require a procedure during mounting, involving the change from heating to cooling while keeping the mount under pressure. This is most readily accomplished by having a split furnace and a split cooling coil or its equivalent in split shells of a metal of high heat capacity to "bleed" the heat from the mold.

TABLE I.—RECOMMENDED MOLDING PRACTICE.

Material	Compound Molding Temperature, deg. Cent.	Compound Molding Pressure, lb. per sq. in.	Softening Point, deg. Cent.	Clarity
		THERMOSETTING TYPE		
Aniline formaldehyde	....	....	None	Opaque
Phenol formaldehyde:				
Wood filler	138–182	1600–6000	None	Opaque
Mineral filler	132–177	1600–6000	None	Opaque
Phenol furfural:				
Wood filler	166–204	1000–3000	Chars at 232 C.	Opaque
Mineral filler	166–182	1000–3000		Opaque
Urea formaldehyde	143–163	1500–6000	None	Translucent to opaque
		THERMOPLASTIC TYPE		
Casein	93–107	2000–2500	93	Translucent to opaque
Vinyl chloride	121–149	1500–2500	54–71	Translucent to opaque
Methyl methacrylate	140–157	1500–5000	77–113	Transparent
Polystyrene	138–163	300–2000	43–93	Transparent
Ethyl cellulose	100–149	1000–5000	60	Transparent
Cellulose acetate	121–177	500–5000	60	Transparent
Cellulose nitrate	85–121	2000–5000	60	Transparent

Where large numbers of samples are to be mounted, it would be advisable to utilize multiple molds whereby several samples could be molded simultaneously.

FORM OF RESINS

The resins are usually obtained as powders, and are introduced into the mold after it and the samples have been heated to the proper molding temperature. Most manufacturers also market these same resins as "pills," that is, cylinders of the resins which are just sufficiently stuck together to hold their shape. These pills can be obtained in a large variety of sizes, shapes, and weights.

The increasing use of electrolytic etching methods requires electric connections to the samples, which can readily be accomplished by attaching a lead to the sample and bringing it upward through the top of the powder or pill. The wire will be pushed down by the descending top plunger of the mold and can be pulled out from the top face of the finished molded sample.

MOLDING PRACTICE

For the guidance of those interested in the use of these materials, Table I shows the recommended molding practice. A more complete table is given in *Modern Plastics*, October, 1937. The trade names under which the products in the table are marketed can readily be obtained by referring to journals specializing in plastics.

The actual technique of mounting a sample consists of bringing the temperature of the mold, and sample too if possible, up to the recommended molding temperature. This should be quite accurately controlled by thermometers or pyrometers. The resin is then introduced in either powder or pill form, the plungers inserted into the mold, and the pressure applied.

It must be kept in mind that the time factor is extremely important in every case. All of these resins are poor heat conductors, nevertheless enough time at temperature must be allowed to thoroughly heat all of the resin to the molding temperature in order that voids will be eliminated. With the thermosetting resins a chemical reaction is also taking place and, in general, the time at temperature is somewhat longer.

It will be found advantageous with some of the resins, particularly the thermoplastics, to build up the pressure rather than to attempt a too rapid application of the full pressure.

Table II shows the operation data for several typical plastics when used to make metallographic mountings:

TABLE II.—OPERATION DATA FOR SEVERAL TYPICAL PLASTICS.

Material	Molding			Cooling		
	Temperature, deg. Cent.	Pressure, lb. per sq. in.	Time, min.	Pressure, lb. per sq. in.	Time, min.	Temperature, deg. Cent.
THERMOPLASTIC TYPE						
Methyl methacrylate I........	145	2500	6	2500	6	75
Methyl methacrylate II.......	160	500–2500	6	2500	7	75
Polystyrene I................	145	2500	5	2500	6	85
Polystyrene II...............	145	2500	5	2500	6	100
THERMOSETTING TYPE						
Aniline formaldehyde..........	140	2500	8–12	None	None	None
Phenol formaldehyde..........	140	2500	8–12	None	None	None

After sufficient time has been given at the proper molding temperature and pressure, the thermosetting plastics can be removed from the hot mold, and another sample mounted.

When the thermoplastic resins have had sufficient time, temperature, and pressure, the furnace or heating source must be removed while the mount is kept under pressure. After removal of the heat supply, either a cooling coil, or other cooling means such as "bleeder" jackets should be placed around the mold to increase the cooling rate. In general, it is advisable to cool the thermoplastic resins to about 75 C. before removing from the mold.

The greatest source of trouble in failing to obtain good molded products may be traced to lack of proper appreciation of the necessity of having all of the resin heated thoroughly to the proper temperature when in the press.

REPORT OF COMMITTEE E-7
ON
RADIOGRAPHIC TESTING

The American Society for Testing Materials was the first industrial society in this country to recognize radiography as a method of routine testing. It was included as a part of X-ray metallography in Subcommittee VI of Committee E-4 on Metallography, which subcommittee was organized in 1925. In 1937, because of the growing commercial importance of this method, the Society authorized the formation of a new standing committee devoted to radiography. Preliminary organization was effected in the fall of that year, permanent officers were selected in February, 1938, and the first regular meeting of the committee was held in Rochester, N. Y., in March, 1938.

At the preorganization meeting held in Atlantic City, N. J., on October 19, 1937, broad lines of policy were outlined by the temporary chairman and supported by those attending the meeting. They were as follows:

1. Committee E-7 should not duplicate work done by other radiographic committees, except where check results are required or other special reason exists. Some duplication of effort may be desirable but the policy should be to cooperate, to correlate, and to avoid duplication.

2. Committee E-7 should have a well-defined sphere of activity and should be careful to keep within it. In accordance with the traditional interests of the Society, this sphere should be related to the improvement of the testing method, to the proper use of the method, and to the establishment of standards whereby radiographic results may be properly evaluated.

3. Committee E-7 must have sufficiently important men in its membership so that its work will carry weight with industry.

4. All industrial groups that are actively engaged in radiographic testing, or that are importantly interested in radiographic results, should be represented in the committee.

Organization of the committee has been effected in conformity with the lines of policy stated above. The membership includes representatives from the various other radiographic and nondestructive test committees, and from all industrial groups importantly interested in radiographic tests of metals.

Subcommittees were appointed as follows:

Subcommittee I on Radiography of Castings (C. W. Briggs, chairman),
Subcommittee II on Technical Research (H. E. Seemann, chairman),
Subcommittee III on Radiography of Welds (H. H. Lester, chairman),
Subcommittee IV on Correlated Abstracts (W. P. Davey, chairman),
Subcommittee V on Publicity, Papers, Technical Programs (Lars Thomassen, chairman), and
Subcommittee VI on Safety (E. W. Page, chairman).

All of the subcommittees have work planned. Considerable progress has been made in the execution of some of these plans. At this annual meeting, Subcommittee V arranged a program of technical papers representing the contributions of Subcommittee II. These are as follows:

"Radiography in Industry,"[1] by H. H. Lester.

"Secondary Radiation in the Radiography of Aluminum, Steel, and Lead," by H. E. Seemann.

"Gamma-Ray Radiography," by Gilbert E. Doan and Shang-Shoa Young.

"A Study of Intensifying Screens for Gamma - Ray Radiography," by Charles W. Briggs and Roy A. Gezelius.

Respectfully submitted on behalf of the committee.

H. H. LESTER,
Chairman.

EARNSHAW COOK,
Secretary.

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[1] Published in ASTM BULLETIN, No. 94, October, 1938, p. 5.

REPORT OF COMMITTEE E-9
ON
RESEARCH

In the following there is presented a brief statement covering some of the outstanding research activities of the various committees of the Society which come under the observation of Committee E-9 on Research, as well as such activities in which the Society is cooperating with other organizations here and abroad. There will be followed this year the longstanding precedent of presenting a detailed review of all the research activities of the committees of the Society in the coming October issue of the *ASTM Bulletin.*

Research Committee Activities:

It was indicated in last year's report that the *Research Committee on Yield Point of Structural Steel* was presenting a report[1] at the 1937 annual meeting which it indicated would be the final chapter in its work. With the publication of this last report and with those previously issued, the committee believed that for the time being the problem had been adequately handled. The committee has therefore been discharged. Certain of the committee's recommendations are being given consideration by Committees A-1 on Steel and E-1 on Methods of Testing, and after study may lead to suggestions for further work.

The Research Committee on Fatigue of Metals is presenting a report at the current meeting of the Society. It will be noted that the committee has outlined a study on "The Effect of Type of Testing Machine on Fatigue Test Results," using a heat-treated alloy steel, an "as-rolled" low-alloy steel, and also possibly an 8 per cent tin bronze. Three types of testing machines will be used and six laboratories will cooperate. In addition to the fatigue tests the committee will make metallographic examinations and determine the Brinell or Rockwell hardness of the bars and accept only those giving results indicating uniformity of metals. It will also make the usual static and notched-bar impact tests. The committee calls attention to the fact that the problem under consideration is one of testing technique and its effect on results and not a study of the fatigue characteristics of any metal.

The Joint Research Committee on Effect of Temperature on the Properties of Metals of The American Society of Mechanical Engineers and this Society is also presenting a report at this meeting of the Society. The marked activity of the committee is indicated by its extensive report, which contains a summary of the various research projects sponsored by the committee, including investigative tests of tubes at elevated temperatures, long-time creep tests on carbon steel K20, investigations of properties of metals at low temperatures, torsion-creep tests for comparison with tension-creep tests, relaxation tests, and the assembly and interpretation of creep test data.

In addition to the detailed report on the work carried on for the committee at Battelle Memorial Institute on the effects of manufacturing variables on high-temperature characteristics and creep resistance of steel, four papers on various features of creep tests of steel are appended to the report. It also contains a completely revised Tentative Method for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 87 (1937).

The Joint Committee on Exposure Tests of Plating on the Non-Ferrous Metals is composed of representatives of the American Electro-Platers' Society, the National Bureau of Standards and this Society. There was presented in the January issue of the *ASTM Bulletin* a brief report of a meeting of the committee at which some supplemental tests were authorized on bright nickel deposits.

The specimens listed in the 1936 report have been exposed in six locations and inspected regularly. To confirm and extend these results, supplemental specimens have been prepared which will be exposed about June 30, 1938. The composition and thickness of the deposits will be included in the detailed report to be submitted at this annual meeting. Arrangements have been made to transfer the Pittsburgh tests from Brunot's Island to the U. S. Bureau of Mines station in Pittsburgh, to obtain a more accessible site and somewhat less severe conditions.

The Joint Committee on Boiler Feedwater Studies has continued its research on the cause and prevention of caustic embrittlement. The subcommittee engaged in this study has concluded from its laboratory work that lignins successfully prevent the development of intercrystalline cracking in steel specimens stressed under a static load or in a reversing torsional load. No confirming experience in stationary boilers is available at the present time; however, in the case of railroad locomotives, lignins and lignin-containing materials have shown evidence of successful performance in this regard. The following further work on aspects of this problem is planned: a more comprehensive study of the effects of chlorides on embrittlement, practicability of the use of lignin as a preventive measure, concentration of boiler water salines in capillary spaces of boilers, study of the tendency of actual boiler water to cause embrittlement, and the problem of caustic embrittlement in boilers operating above 500-lb. pressure.

The research directed towards the development of a more exact method for determining traces of dissolved oxygen has been completed and a report referred to the Society's Committee D-19 on Water for Industrial Uses for consideration in its program of issuing standard methods for the analysis of water.

The work on coagulation and sedimentation is still in the formative stage.

No active research program is contemplated on the general subject of corrosion save the above-mentioned study of intercrystalline cracking and a study of the reaction between steel and steam at high temperatures, being carried out principally at Purdue University.

The committee has prepared an excellent report on the subject of patents in the field of boiler feedwater treatment.

Special Research:

Research on the Standardization of pH Measurements.—At the last meeting of the Society a paper on the need for pH standardization was presented by Dr. S. F. Acree.[1] Under the sponsorship of Committee D-19 on Water for Industrial Uses, this matter has been brought to the attention of the various committees of the Society through the Research Committee and has been discussed at considerable length by the Research Committee. There is no doubt that many committees are interested in standardization of pH determinations and that some intensive work is needed. Before carrying this out, financial assistance is needed to an extent that cannot be met by the Society's research funds. It is to be hoped that with further discussion within the various committees means can be found to start this work at least in part.

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[1] Baker Wingfield, W. H. Goss, Walter J. Hamer, and S. F. Acree, "The Need for pH Standards," ASTM BULLETIN, No. 90, January, 1938, p. 15.

Methods for Capping Structural Clay Tiling.—The Society by a grant from its research funds is assisting in a study of developing materials and methods for capping clay tile at Rensselaer Polytechnic Institute, under the direction of Prof. T. R. Lawson, for Committee C-15 on Manufactured Masonry Units. The facilities of the Institute have been gratuitously offered for this work. The effects on the compressive strength of tile caused by the use of different materials for filling the recesses in the bearing faces are being determined. It is expected that a report on the investigation will be presented at the annual meeting.

Research on the Effect of Speed of Testing of Concrete.—This problem which was aided by a grant from the Society's research funds has been carried on at the Engineering Experiment Station of the University of Illinois, under Prof. F. E. Richart. The results have been presented in two papers, and with the presentation of the second, "Short-Time Creep Tests of Concrete in Compression," at this meeting, the work has been completed. It is interesting to note that this study, carried on through the advice of Committees E-1 on Methods of Testing and C-9 on Concrete and Concrete Aggregates, has led Committee E-1 to request a grant from the Society's research funds to use in applying the same general methods to a similar study to be confined to metals.

Research on the Correlation of Fundamental Properties of Paint Coatings and Service Tests.—Committee D-1 on Paint, Varnish, Lacquer, and Related Products has been considering a research of some phases of the fundamental properties of paint coatings and has selected the subject of adhesion and adhesion testing of paint for possible development. A group is at work now in the committee outlining such a project and developing a program of work to be accomplished. This proposed study is of such a comprehensive nature that it will require the active interest and financial support of those industries that are concerned with this important problem in the utilization of paints as protective coatings.

Research Committees of Other Societies:

The Society is represented on the Advisory Committee of the Highway Research Board, National Research Council, by Prévost Hubbard; on the Special Research Committee on Mechanical Springs of The American Society of Mechanical Engineers by C. T. Edgerton; and on the Engineering Foundation Welding Research Committee by N. L. Mochel.

Highway Research Board.—An item of particular interest being discussed by the Department of Materials and Construction of this Board, is that of the characteristics of asphalt. The Project Committee has presented a report dealing with a cooperative study designed to determine if asphalts of different types and from different sources showed any variation in their resistance to film stripping when used to coat hydrophilic aggregate. The committee also sent a questionnaire to highway engineers throughout the country for the purpose of ascertaining what problems in connection with asphalt construction were of greatest importance at the present time. This questionnaire has been analyzed and the results will likely be published. The reports of the various project committees under this Department are published in the Annual Proceedings of the Highway Research Board.

Mechanical Springs.—The program of fatigue tests on full-size railway-type helical compression springs has been continued at Wright Field under the sponsorship of the A.S.M.E. committee. Stress-endurance graphs have been developed for springs of plain-carbon basic electric-furnace steel, basic open-hearth steel, and acid open-hearth steel. The endurance limits found for the three grades were nearly the same, the electric steel showing best by a slight margin. The next step in the project is an investigation of the effect of surface finish on endurance. Four more groups of springs are now undergoing the calibration tests. They represent, respectively, "as-rolled" bars from specially prepared billets, cold-drawn bars, centerless ground bars, and cold-drawn bars cold coiled into springs. Work on this project went very slowly up to quite a recent stage, owing to economic conditions, to dearth of special testing machines adapted to this kind of research, and to the fact that a special testing technique had to be developed from almost nothing.

Welding Research. — Subcommittees have been organized to plan and carry out studies dealing with the following in so far as they apply to welding:

Plain-carbon steels,
Low-alloy steels,
High-alloy steels,
Aluminum alloys,
Copper alloys,
Nickel alloys,
Methods of testing,
Weld stresses, causes and effects,
Non-destructive tests,
Resistance welding, and
Fatigue tests.

Research Progress of A.S.T.M. Committees:

The annual review of the progress of research in the various committees of the Society will be published in the coming October issue of the *Bulletin.* The review in the October, 1937, issue has been reprinted and copies may be obtained from Society headquarters.

The following numerical tabulation of research projects should be of interest to all members of the Society:

		TOTAL NUMBER	PROGRESS REPORTED IN 1937	NEW
I. Research on Properties of Materials		48	20	2
II. Research on Methods of Testing		91	36	13
		139		
Projects finished in I	4			
Projects dropped in II	2	6		
Present Total Active Projects { I ..... 45, II ..... 89 }		133	56	15

New Activities.—Since the last report of the committee, the following new research activities have been originated and in a number of cases substantial progress made:

Fatigue Tests of Cast Iron (Committee A-3).—Study of effects of understressing and overstressing on endurance limit of cast iron.

Investigation of Tin- and Lead-Base Die-Casting Alloys (Committee B-6).—A study of 5 tin-base and lead-base alloys to determine tensile strength, creep, impact, and hardness. Composition of the alloys will be determined by chemical and spectrographic analyses.

Tests for Weight or Thickness of Plated Coatings (Committee A-5).—Studies of several methods, including metallographic, stripping, the chord method, dropping, jet, and spot tests, and a newly developed magnetic method for nickel coatings.

Tests for Metallic Materials for Radio Tubes and Incandescent Lamps (Committee B-4).—Proposed program divided among five sections: on strip, wire, tubing, coated material, and powdered materials and liquids. Immediate work to cover preparation of test methods for the temper of wire and for thin sheets of metal used in radio tubes.

Effect of Controlled Atmospheres Upon Electric-Furnace Resistors and Structures (Committee B-4).—Study of a suitable method of test to determine the durability of resistor alloys exposed to controlled atmospheres at high temperatures in electric furnaces.

Tests for Light Metals (Committee B-7).—Study of various problems relating to testing of aluminum alloys and magnesium alloys, including tensile properties, hardness tests, effect of speed of testing, effect of foundry technique on physical properties of cast test bars including effects of design, gating and chilling.

Capping Structural Clay Tile (Committee C-15).—Investigation of methods of capping structural clay tile, comparisons to be obtained between various types of filling for the recesses of bonding tile as well as between different materials for capping. Tests carried out at Rensselaer Polytechnic Institute.

Studies of Size of Samples for Fire Tests of Materials and Construction (Committee C-5).—Scope of studies includes (1) inquiry into the effect of size of samples on test results; (2) what types of information can be obtained on samples smaller than the standard size for given types of construction; (3) under what conditions information on load-carrying ability can be obtained from temperature measurements without load application; and (4) the necessary distribution of thermocouples and other measuring appliances to obtain reliable results.

Tests of Plant Spray Oil (Committee D-2).—Method of test for distillation of plant spray oils issued as tentative and a test for unsulfonated residue of plant spray oils published as information.

Vapor Pressure of Petroleum Products (Committee D-2).—Study of two existing test procedures (Methods D 323 and D 417) for vapor pressure (Reid method) to determine (1) whether 28 lb. is the proper upper limit of application of Method D 417, (2) if Method D 417 is practical for use in natural-gasoline plant laboratories, and (3) what vapor-pressure method should be prescribed for natural gasolines above the upper limit of application of Method D 417. A single revised method D 323 has resulted from this work.

Tests for Water-Soluble Salts in Asphalt-Salt Mixtures (Committee D-4).—A series of cooperative tests on asphalt-salt mixtures conducted during past year.

Ignitability of Coal and Coke (Committee D-5).—Investigation of laboratory tests for determination of ignition temperatures of fuels.

Tests of Liquid Rubber Products (Committee D-11).—Formulation of standard methods of test for the evaluation of rubber cements and rubber latex. Work on cements will include tests for viscosity and determination of total solids; and on latex, methods will be investigated for color, total solids, dry rubber content, ammonia, and hydrogen ion concentration.

Tests for Bast Fibers and Their Products (Committee D-13).—Studies under way on breaking strength, fiber length determination, and numbering of jute yarns.

Tests for Soils for Engineering Purposes (Committee D-18).—Study and formulation of standard methods of procedure for the following tests of soils for engineering purposes: Physical characteristics, compressibility and elasticity, shearing properties, mechanical stability, load capacity of soil in place, bearing capacity of piles, and drainage properties.

International Projects:

Cooperation with the British Iron and Steel Institute.—In this research, ingot-iron panels supplied by the Corrosion Committee of the British Iron and Steel Institute and panels of zinc of good quality, supplied through the courtesy of the New Jersey Zinc Co., after careful weighing have been exposed on the Committee A-5 test racks at Sandy Hook, N. J., the Pennsylvania State College Farm, at State College, Pa., and Brunot Island (Pittsburgh), Pa. The exposure tests were started in October, 1937.

International Coordination of Corrosion Work.—In last year's report of the Research Committee attention was called to the large amount of research being carried out both abroad and in this country in connection with the study of the corrosion of all types of metals. There has been an interesting development since then of the suggestion that this Society act as the clearing house for the work in the United States. At the Regional Meeting in Rochester an informal conference of representatives of a group of societies was held for the purpose of considering what might effectively be done, first, as to setting up a clearing house so that investigators on corrosion throughout our own country can be kept informed of each other's programs of work; and, second, to utilize such a group if possible for maintaining contacts with similar groups abroad. As a result of the conference a study group of three was appointed to work on plans for setting up what might be called an

American Coordinating Committee on Corrosion. The report of this study committee is to be reviewed at a second conference to be held sometime during the current meeting.

Administrative Matters. — With this meeting the term of P. H. Bates expires and C. E. MacQuigg, Dean of College of Engineering, Ohio State University, has been appointed to succeed him.

The principal of the A.S.T.M. Research Fund is now $21,478.18. Since the report a year ago the principal was augmented by the addition of $1680 from the entrance fees for 1937, transfer of a small balance in the funds of Committee D-14 on Screen Wire Cloth when that committee was disbanded, and a contribution of $150 from Past-President H. F. Moore, Past-Chairman of Committee E-9.

The balance of income in the Research Fund on May 31, 1938, was $1265.37, of which approximately $375 has been appropriated towards the following four projects: Completion of the structural clay tile capping tests of Committee C-15, certain soil tests of Committee D-18, some incidental expenses in connection with preparation of mica samples for Committee D-9, and incidental expenses for Committee A-5 in connection with the cooperative corrosion tests with the British Iron and Steel Institute.

Respectfully submitted on behalf of the committee,

P. H. BATES,
Chairman.

C. L. WARWICK,
Secretary.

REPORT OF COMMITTEE E-10
ON
STANDARDS

In addition to a review of the Society's standardization activities in general and taking action on recommendations with respect to new tentative standards and revisions submitted to it in the interval between annual meetings, Committee E-10 on Standards has the very important function of considering what fields of materials standardization, in addition to those already covered, would seem to justify development either by committees already functioning or through the organization of new committees. The past few years have been particularly interesting ones in this connection for they have seen quite a number of new projects gotten under way, as for example, the work on plastics, paper, soaps, and soils. The past year has been no exception for since the last annual meeting a new Committee on Thermal Insulating Materials has been organized to cover a very important and fast expanding field; work on radiography has progressed to a stage where it has warranted the formation of a new committee and, further, the Committee on Mortars for Unit Masonry, which has been inactive during the past few years, has been revived. These several developments are discussed later in the report.

The activities of Committee E-10 on Standards during the past year are set forth under the following heads: Review of A.S.T.M. standardization activities, consideration of new and revised standards and tentative standards, promotion and expansion of standardization activities, relations with American Standards Association, and contacts with the International Standards Association.

As in the previous year, a very considerable number of new tentative standards and revisions of existing standards and tentative standards have been submitted to Committee E-10 during the year for approval. For the most part these were considered at the regular meeting of the committee held in Philadelphia, Pa., on August 26, 1937.

The Executive Committee of the Society reappointed J. O. Leech of the Carnegie-Illinois Steel Corp. and J. B. Young of the Reading Co. to serve as members of Committee E-10 for a three-year term, expiring in 1940.

REVIEW OF A.S.T.M. STANDARDIZATION ACTIVITIES

A general summary of the new tentative standards submitted at the 1937 annual meeting, of tentative standards adopted as standard, and of revisions in standards, was included in the August issue of the *ASTM Bulletin*, together with a review of the standardization work of the various committees with statements concerning new standards in prospect. Much of the information, particularly in respect to standardization projects under development in committees, is furnished by the standing committees subsequent to the annual meeting and takes advantage of the fact that many committees plan their next year's work at committee meetings held during the annual meeting.

At the present writing, it is possible

to make only a preliminary estimate in terms of new and revised standards of the volume of standardization work accomplished during the year and reported to the Society at this meeting. The reports of standing committees to be presented at the annual meeting include recommendations to the Society substantially as follows:

New tentative standards	71
Revisions of existing tentative standards	59
Tentative revisions of existing standards	37
Tentative standards recommended for adoption as standard	32
Revisions of existing standards recommended for adoption as standard	33
Standards and tentative standards withdrawn	36

There are at present 511 standards and 313 tentative standards of the Society, making a total of 824, and if the above recommendations are approved this total will become 859.

CONSIDERATION OF NEW AND REVISED STANDARDS

Proposed new standards approved by Committee E-10 and published as tentative during the year are as follows:

Tentative Specifications for:

Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 37 T), submitted by Committee A-1 on Steel,

Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F. (A 206 – 37 T), submitted by Committee A-1,

Rolled Wrought-Iron Shapes and Bars (A 207 – 37 T), submitted by Committee A-2 on Wrought Iron,

Phenolic Laminated Sheet for Radio Applications (D 467 – 37 T), submitted by Committee D-9 on Electrical Insulating Materials,

Rubber Gloves for Electrical Workers on Apparatus or Circuits not Exceeding 3000 Volts to Ground (D 120 – 37 T), submitted by Committee D-11 on Rubber Products,

Insulated Wire and Cable: Heat-Resisting Rubber Compound (D 469 – 37 T), submitted by Committee D-11, and

Fineness of Wool Tops (including methods of test) (D 472 – 37 T), submitted by Committee D-13 on Textile Materials.

Tentative Methods of:

Test for Sediment in Fuel Oil in Extraction (D 473 – 38 T), submitted by Committee D-2 on Petroleum Products and Lubricants,

Testing Films Deposited from Bituminous Emulsions (D 466 – 37 T), submitted by Committee D-8 on Bituminous Waterproofing and Roofing Materials,

Testing Pin-Type, Lime Glass Insulators (D 468 – 37 T), submitted by Committee D-9 on Electrical Insulating Materials,

Testing Rubber Hose (D 380 – 37 T), submitted by Committee D-11 on Rubber Products,

Testing Rubber Insulated Wire and Cable (D 470 – 37 T), submitted by Committee D-11, and

Test for Changes in Properties of Rubber and Rubber-Like Materials in Liquids (D 471 – 37 T), submitted by Committee D-11.

Revisions of the following tentative standards and standards were accepted by Committee E-10:

Tentative Specifications for:

Alloy-Steel Bolting Materials for High-Temperature Service from 750 to 1100 F., Metal Temperatures (A 193 – 37 T), submitted by Committee A-1 on Steel,

Paving Brick (C 7 – 37 T), submitted by Committee C-15 on Manufactured Masonry Unit,

Glazed Building Units (C 126 – 36 T), submitted by Committee C-15,

Fuel Oils (D 396 – 38 T), submitted by Committee D-2 on Petroleum Products and Lubricants,

Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 37 T), submitted by Committee D-11 on Rubber Products, and

Insulated Wire and Cable: Performance Rubber Compound (D 353 – 37 T), submitted by Committee D-11.

Tentative Methods of:

Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 37 T), submitted by Committee D-9 on Electrical Insulating Materials,

Quantitative Spectrochemical Analysis of High Grade Pig Lead (E 25 – 37 T), submitted by Committee E-2 on Spectroscopic Analysis, and

Quantitative Spectrochemical Analysis of Zinc Alloy Die Castings for Minor Constituents and Impurities (E 27 – 37 T), submitted by Committee E-2.

Tentative Definitions of:

Terms Relating to Rheological Properties of Matter (E 24 – 37 T), submitted by Committee E-1 on Methods of Testing.

Standard Specifications for:

Boiler and Firebox Steel for Locomotives (A 30 – 33), submitted by Committee A-1 on Steel,

Iron and Steel Chain (A 56 – 30), submitted by Committee A-2 on Wrought Iron,

Staybolt Wrought Iron, Solid (A 84 – 36), submitted by Committee A-2, and

Staybolt Wrought Iron, Hollow Rolled (A 86 – 36), submitted by Committee A-2.

Standard Method of:

Test for Softening Point of Tar Products (Cube-in-Water Method) (D 61 – 24), submitted by Committee D-4 on Road and Paving Materials.

The withdrawal of the following standards which were replaced by new specifications and methods was approved by Committee E-10:

Standard Specifications for:

Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 36), on the recommendation of Committee A-1 on Steel, and

Rubber Gloves for Electrical Workers on Apparatus or Circuits not Exceeding 3000 Volts to Ground (D 120 – 23), on the recommendation of Committee D-11 on Rubber Products.

Standard Methods of:

Test for Rubber Hose—Braided Construction (D 379 – 36), on the recommendation of Committee D-11, and

Test for Rubber Hose—Wrapped Construction (D 380 – 36), on the recommendation of Committee D-11.

PROMOTION AND EXPANSION OF STANDARDIZATION ACTIVITIES

Authorization was granted by the Executive Committee for the organization of two new standing committees of the Society, as follows: Committee E-7 on Radiographic Testing and Committee C-16 on Thermal Insulating Materials.

Committee E-7 is an outgrowth of the activities of Committee E-4 on Metallography which for some years has had a subcommittee functioning in this field, including not only the radiographic studies but also an investigation of diffraction methods. The new committee is to deal with the subject of radiographic testing in more general terms than was the case heretofore in Committee E-4; the subject of X-ray diffraction, however, is to remain with Committee E-4. Committee E-7 held its organization meeting in New York City on February 14, 1938, and is now functioning under the chairmanship of H. H. Lester of Watertown Arsenal.

Committee C-16 was organized to fill a definite need for standardization in the field of thermal insulation. While the Society's standards have provided for most of the engineering materials, no work had ever been attempted in the field of thermal insulation aside from that of Committee C-8 on Refractories with respect to high-temperature insulations. The new committee will deal with the so-called industrial insulating materials for use at moderately high temperatures. While the scope is limited, at least for the present, to this particular field it is recognized that many of the tests that need to be developed will no doubt be of interest to the low-temperature field also. One meeting of the committee was held in Rochester, N. Y., on March 10, 1938, and a further meeting to complete the organization of the committee is being held during the present annual meeting. Mr. J. H. Walker of the Detroit Edison Co. is serving as temporary chairman.

In view of the definite need for work in the field of mortars for unit masonry, Committee C-12, which was discharged by the Executive Committee in 1935, was reorganized at a meeting held in Washington, D. C., on November 4, 1937. Mr. J. W. McBurney of the National Bureau of Standards was elected chairman. The reconstituted committee is functioning with a much smaller personnel so as to expedite its work, since it was partly due to an unwieldy personnel and subcommittee organization that the earlier Committee C-12 failed to function.

Consideration is still being given to the subject of sulfur-base jointing compounds. It is now proposed to hold a conference of all those interested in jointing compounds, perhaps looking into the possibility at the same time of organizing a general committee on jointing and calking compounds, having in mind the pipe jointing compounds, the masonry calking compounds, road-joint fillers, etc.

The question of undertaking work in the field of chemicals used in electroplating has been discussed with the American Electro-Platers' Society. It has developed that there may be some further discussion of this question in the A.E.S. and the subject is being held in abeyance pending the outcome of these proposed discussions.

The preparation of specifications for industrial chemicals, such as for sulfuric acid, etc., has also received attention, especially since the question has been raised as to whether there should be some attempt at international standardization.

RELATIONS WITH AMERICAN STANDARDS ASSOCIATION

Standards Submitted Under Existing Standards Procedure.—The existing standards procedure for submitting standards to the American Standards Association is particularly appropriate for a large number of A.S.T.M. standards. Under this procedure the following standards have been approved during the year by the A.S.A. as American standards:

Standard Specifications for:

Bronze Trolley Wire (B 9 – 37) (A.S.A. No. H22.1–1937),
Copper Trolley Wire (B 47 – 37) (A.S.A. No. H22.2–1937),
Spirits of Turpentine (D 13 – 34) (A.S.A. No. K32–1937),
Raw Linseed Oil (D 234 – 28) (A.S.A. No. K34–1937),
Boiled Linseed Oil (D 260 – 33) (A.S.A. No. K35–1937),
Bone Black (D 210 – 30) (A.S.A. No. K36–1937),
Chrome Oxide Green (D 263 – 28) (A.S.A. No. K37–1937),
Titanium Barium Pigment (D 382 – 35) (A.S.A. No. K38 – 1937),
Titanium Calcium Pigment (D 383 – 35) (A.S.A No. K39–1937), and
Titanium Dioxide (D 384 – 36) (A.S.A. No. K40–1937).

Standard Methods of:

Test for Determination of Voids in Aggregate for Concrete (C 30 – 37) (A.S.A. No. A19–1937),
Routine Analysis of Dry Red Lead (D 49 – 37) (A.S.A. No. K16.1–1937),
Sampling and Testing Turpentine (D 233 – 36) (A.S.A. No. K33–1937),
Test for Specific Gravity of Pigments (D 153 – 27) (A.S.A. No. K41–1937),
Test for Coarse Particles in Dry Pigments and Coarse Particles and Skins in Mixtures of Pigments and Vehicles (D 185 – 37) (A.S.A. No. K42–1937),
Routine Analysis of Titanium Pigments (D 186 – 37) (A.S.A. No. K43–1937),
Routine Analysis of Yellow, Orange, Red and Brown Pigments Containing Iron and Manganese (D 50 – 36) (A.S.A. No. K44–1937), and
Laboratory Sampling and Analysis of Coal and Coke (D 271 – 37) (A.S.A. No. K18–1937).

Standards Submitted Under Sectional Committee Procedure.—Reports were received from several of the sectional committees, for which the Society is sponsor, submitting standards to the A.S.A. for approval. These reports have been transmitted to that association and the following standards have been approved during the year as American standards with the exception of three which have been approved as American tentative standards as indicated:

On the Recommendation of Sectional Committee C59 on Electrical Insulating Materials:

Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 37) (A.S.A. No. C59.1–1938), and

Tentative Specifications and Tests for Rubber Insulating Tape (D 119 – 35 T) (A.S.A. No. C59.6–1938), approved as American tentative standard.

On the Recommendation of Sectional Committee M20 on Classification of Coals:

Standard Specifications for Classification of Coals by Rank (D 388 – 37) (A.S.A. No. M20.1–1937), and

Standard Specifications for Classification of Coals by Grade (D 389 – 37) (A.S.A. No. M20.2–1937).

On the Recommendation of Sectional Committee Z11 on Petroleum Products and Lubricants:

Standard Method of Test for Melting Point of Paraffin Wax (D 87 – 37) (A.S.A. No. Z11.4–1937),

Standard Method of Analysis of Grease (D 128 – 37) (A.S.A. No. Z11.16–1937),

Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 37) (A.S.A. No. Z11.31–1937),

Tentative Method of Test for Knock Characteristics of Motor Fuels (D 357 – 37 T) (A.S.A. No. Z11.37–1937), approved as American tentative standard, and

Tentative Standard Viscosity-Temperature Charts for Liquid Petroleum Products (D 341 – 37 T) (A.S.A. No. Z11.39–1937), approved as American tentative standard.

Sectional Committees Organized.—A Sectional Committee on Valid Certification (A.S.A. Project: Z34) has been organized under the procedure of the American Standards Association. The Society is interested in this subject and has appointed as its representative on the committee, T. G. Delbridge of the Atlantic Refining Co.

A Sectional Committee on Building Code Requirements for Excavations and Foundations (A.S.A. Project: A56) is now being organized by the A.S.A. It appears that the work of this committee will bear a very close relation to that of the Society's Committee D-18 on Soils for Engineering Purposes and consideration is accordingly being given to the appointment on the committee of an A.S.T.M. representative.

International Standards Association.—Committee E-10 has continued to follow the activities of the various committees functioning under the International Standards Association. At the present time the following international committees are functioning, on which American industry is represented through the A.S.A. In each instance the nominations for representatives have been made by the A.S.T.M.:

I.S.A. Technical Committees:

No. 17 on Specifications for Iron and Steel, F. N. Speller,

No. 24 on Sieves for Testing Purposes, L. V. Judson,

No. 27 on Sampling and Analysis of Coal, A. C. Fieldner,

No. 28 on Nomenclature and Methods of Test of Petroleum Products, R. P. Anderson,

No. 33 on Standards for Refractory Materials, S. M. Phelps (R. S. Bradley, alternate),

No. 35 on Raw Materials Used in the Manufacture of Paints, H. A. Gardner (M. Rea Paul, alternate),

No. 38 on Textiles, representation through chairman of Committee D-13 and

No. 45 on Rubber Products, S. Collier and W. E. Emley.

The last two committees have been organized during the past year.

Mr. Speller has asked to be relieved of his connection with the work of Technical Committee No. 17 on Specifications for Iron and Steel and consideration is now being given to having American representation held through the chairman of A.S.T.M. Committee A-1 on Steel.

The committee re-elected the present chairman for the ensuing term of two years.

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

C. L. WARWICK,
Ex-officio Secretary.

A.S.T.M.
TENTATIVE STANDARDS

ISSUED OR REVISED, 1938

The term Tentative Standard is applied to a proposed Standard which is printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action toward its adoption as standard.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Standards to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

**A.S.M.E. BOILER CONSTRUCTION CODE
SPECIFICATION No.: S-17**

Tentative Specifications for

LAP-WELDED AND SEAMLESS STEEL AND LAP-WELDED IRON BOILER TUBES[1]

A.S.T.M. Designation: A 83 – 38 T

ISSUED AS TENTATIVE 1921; ADOPTED IN AMENDED FORM, 1924;
REVISED, 1927, 1930, 1933, 1934, 1936; REISSUED AS TENTATIVE, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. (*a*) These specifications cover lap-welded and seamless steel, and lap-welded iron, boiler tubes and boiler flues, including safe ends, arch and stay tubes, and seamless superheater and small boiler tubes.

(*b*) The diameters and wall thicknesses of tubes covered by these specifications are shown in Table I.

Process

2. (*a*) The material for lap-welded or seamless steel tubes shall be made by either or both of the following processes: open-hearth or electric-furnace. The material for open-hearth iron tubes shall be made by the open-hearth process.

(*b*) The material for wrought-iron tubes shall be made by the knobbled, hammered charcoal-iron process.

Chemical Composition

3. (*a*) Chemical analysis will not be required for charcoal-iron tubes.

(*b*) Material made by the open-hearth or electric-furnace processes shall conform to the following requirements as to chemical composition:

	Grade A Low-Carbon Steel	Grade B Open-Hearth Iron
Carbon, per cent....	0.08 to 0.18	0.03, max.
Manganese, per cent.	0.30 to 0.60	0.03, max.
Phosphorus, max., per cent..........	0.04	0.02
Sulfur, max., per cent.............	0.045	0.045

Check Analyses

4. (*a*) Analyses of two tubes in each lot of 250 lengths, or fraction thereof, and in each lot of 2000 ft., or fraction thereof, of safe-end material may be made by the purchaser. Drillings for analysis shall be taken from several points around each tube selected for analysis. The chemical composition thus determined shall conform to the requirements specified in Section 3 (*b*).

(*b*) If the analysis of either tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 3 (*b*).

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[1] Under the standardization procedure of the Society, these specifications are under the joint jurisdiction of the A.S.T.M. Committee A-1 on Steel and Committee A-2 on Wrought Iron.

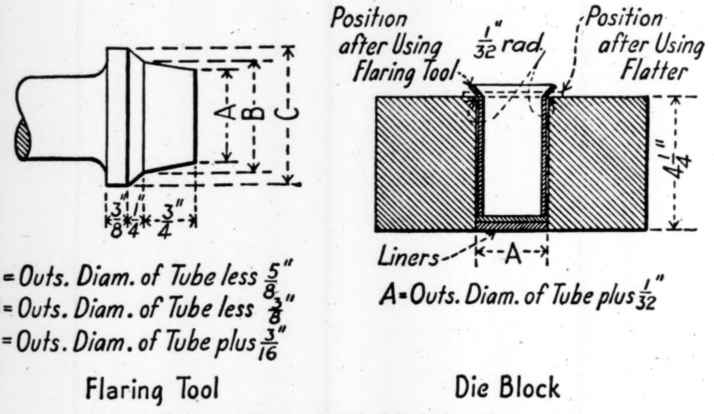
These specifications are in effect a revision of and replace Grades A and B of the former Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 36), which standard was accordingly discontinued in 1938.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Flattening Tests

5. (*a*) For tubes having a wall thickness[3] not more than 10 per cent of the outside diameter, and providing the thickness does not exceed 0.200 in., a section of tube $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates, without cracking or showing any flaw, until the distance between the plates is as follows:

For seamless tubes....three times the wall thickness
For lap-welded tubes....five times the wall thickness



Position after Using Flaring Tool
$\frac{1}{32}$" rad.
Position after Using Flatter
A
B
C
$\frac{3}{8}$"
$\frac{1}{4}$"
$\frac{3}{4}$"
$4\frac{1}{4}$"
Liners
A
A = Outs. Diam. of Tube less $\frac{5}{8}$"
B = Outs. Diam. of Tube less $\frac{3}{8}$"
C = Outs. Diam. of Tube plus $\frac{3}{16}$"
A = Outs. Diam. of Tube plus $\frac{1}{32}$"
Flaring Tool
Die Block

FIG. 1.—Flaring Tool and Die Block for Flange Test.

(*b*) For tubes other than specified in Paragraph (*a*), a section of tube $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates, without cracking or showing any flaw, until the distance between the plates is as follows:

For seamless tubes....four times the wall thickness
For lap-welded tubes....six times the wall thickness

NOTE.—In the case of lap-welded charcoal-iron tubes over 0.200 in. in thickness the test shall be made with the weld 45 deg. away from the point of maximum bend. For other lap-welded charcoal-iron tubes and for all steel lap-welded tubes covered by Paragraphs (*a*) and (*b*), the test shall be made with the weld at the point of maximum bend.

Flange Test

6. (*a*) For tubes having a wall thickness[3] less than 10 per cent of the outside diameter, and providing the thickness does not exceed 0.200 in. a section of tube not less than 4 in. in length shall be capable of having a flange turned over at right angles to the body of the tube without cracking or showing any flaw. This flange, as measured from the outside of the tube, shall in no case be less than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. Within these limits, the width of flange, shall be not less than the following:

OUTSIDE DIAMETER OF TUBE, IN	WIDTH OF FLANGE CHARCOAL IRON	OPEN-HEARTH OR ELECTRIC FURNACE GRADES A AND B
2½ and under	12.5 per cent of outside diameter	15 per cent of outside diameter
Over 2½ to 3¾	⅜ in.	⅜ in.
Over 3¾ to 6	10 per cent of outside diameter	10 per cent of outside diameter

(*b*) For tubes other than specified in Paragraph (*a*) the flange test will not be required.

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[3] The term wall thickness shall be defined as the actual mean wall thickness of the material tested.

(*c*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Crush Test

7. When required by the purchaser, crushing tests shall be made on sections of tube $2\frac{1}{2}$ in. in length which shall stand crushing longitudinally, without cracking, splitting, or opening at the weld, as follows. Slight surface checks shall not be cause for rejection.

Wall Thickness of Tubes	Height of Crushed Section	
	Grades A and B Tubes	Charcoal-Iron Tubes
0.135 in. and under......	¾ in. or until outside folds are in contact	1⅛ in.
Over 0.135 in............	1¼ in.	1½ in.

Hydrostatic Test

8. (*a*) Prior to upsetting, swaging, expanding, bending, or other forming operations, each tube shall be tested at the mill to the hydrostatic pressures as follows (Note 2): Tubes under 5 in. in diameter shall withstand an internal hydrostatic pressure of 1000 psi., and tubes 5 in. or over in diameter shall withstand an internal hydrostatic pressure of 800 psi., provided the fiber stress corresponding to these pressures does not exceed 16,000 psi., as determined by the following formula. Should the fiber stress corresponding to these pressures exceed the above figures, the hydrostatic test pressure shall be determined by the following formula:

$$P = \frac{2\,St}{D}$$

where:

P = the hydrostatic test pressure in pounds per square inch,

S = the allowable fiber stress of 16,000 psi.,

t = the thickness of the tube wall in inches, and

D = the outside diameter of the tube in inches.

NOTE 2.—When requested by the purchaser and so stated on the order, tubes shall be tested to one and one-half times the specified working pressure (when one and one-half the specified working pressure exceeds the test pressures stated in Section 8 (*a*)), provided the fiber stress corresponding to those test pressures does not exceed 16,000 psi., as determined by the above formula.

(*b*) Lap-welded tubes shall be struck near both ends, while under the test pressure, with a 2-lb. steel-hand hammer or its equivalent.

Etch Test for Charcoal-Iron Tubes

9. To determine that a tube is charcoal iron, a cross-section of the tube may be turned or ground to a true surface, polished free from dirt or cracks, and etched[4] until the soft parts are sufficiently dissolved to show a decided ridged surface, with the weld very distinct. A steel tube so etched would show an even or homogeneous surface.

Test Specimens

10. (*a*) Test specimens shall be taken from finished tubes. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested at room temperature.

Number of Tests

11. (*a*) One each of the tests specified in Sections 5, 6, and 7 shall be made on each of two tubes from each lot of 250 tubes, or fraction thereof, and each 2000 ft., or fraction thereof, of safe-end material.

(*b*) Each tube shall be subjected to the hydrostatic test specified in Section 8.

Retests

12. If the results of the physical tests of either of the tubes selected for test do not conform to the requirements specified in Sections 5, 6, and 7, retests shall

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[4] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 0 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42) and 75 per cent water, is recommended for the etch test.

TABLE I.—STANDARD WEIGHTS OF LAP-WELDED AND SEAMLESS BOILER TUBES, INCLUDING SAFE ENDS, ARCH AND STAY TUBES, AND SEAMLESS SUPERHEATER AND SMALL BOILER TUBES.

NOTE.—For sizes 5 in., 5¼ in., 5⅜ in., and 5½ in. in outside diameter, charcoal-iron tubes are not manufactured with walls less than approximately No. 9 B.w.g. (0.150 in.), and tubes with an outside diameter of 6 in. are not manufactured with walls less than No. 7 B.w.g. (0.180 in.).

Wall Thickness, in.	0.035	0.040	0.045	0.050	0.055	0.065	0.075	0.085	0.095	0.105	0.120	0.135	0.150	0.165	0.180	0.200	0.220	0.240	0.260	0.280	0.300	0.320
Wall Thickness, nearest B.w.g. No.	20	19−	19+	18+	17−	16	15+	14+	13	12−	11	10+	9+	8	7	6−	5	4+	3+	2−	1	0
Size, Outside Diameter, in.	Weight, lb. per ft. of length																					
½	0.1738	0.1965	0.2187	0.2403	0.2614	0.3020	0.3404	0.3767	0.4109	0.4430	......	......	......	......	......	......	......	......	......	......	......	......
⅝	......	......	0.2787	0.3071	0.3348	0.3888	0.4406	0.4902	0.5377	0.5831	......	......	......	......	......	......	......	......	......	......	......	......
11/16	......	......	0.3090	0.3407	0.3718	0.4325	0.4910	0.5474	0.6017	0.6538	0.7279	......	......	......	......	......	......	......	......	......	......	......
¾	......	......	0.3388	0.3738	0.4082	0.4755	0.5407	0.6037	0.6646	0.7233	0.8074	0.8867	......	......	......	......	......	......	......	......	......	......
13/16	......	......	......	0.4074	0.4452	0.5193	0.5911	0.6609	0.7285	0.7940	0.8881	0.9775	......	......	......	......	......	......	......	......	......	......
⅞	......	......	......	0.4406	0.4817	0.5623	0.6408	0.7172	0.7914	0.8635	0.9676	1.067	1.161	......	......	......	......	......	......	......	......	......
15/16	......	......	......	......	0.5187	0.6060	0.6913	0.7744	0.8553	0.9341	1.048	1.158	1.262	......	......	......	......	......	......	......	......	......
1	......	......	......	......	0.5551	0.6491	0.7409	0.8306	0.9182	1.004	1.128	1.247	1.362	1.471	......	......	......	......	......	......	......	......
1⅛	......	......	......	......	0.6285	0.7359	0.8411	0.9441	1.045	1.144	1.288	1.427	1.562	1.692	......	......	......	......	......	......	......	......
1 3/16	......	......	......	......	......	0.7796	0.8915	1.001	1.109	1.214	1.369	1.518	1.663	1.803	1.938	2.110	......	......	......	......	......	......
1¼	......	......	......	......	......	0.8226	0.9412	1.058	1.172	1.284	1.448	1.608	1.762	1.912	2.057	2.243	......	......	......	......	......	......
1⅜	......	......	......	......	......	0.9094	1.041	1.171	1.299	1.424	1.608	1.788	1.962	2.132	2.297	2.510	......	......	......	......	......	......
1 7/16	......	......	......	......	......	......	1.092	1.228	1.363	1.495	1.689	1.879	2.063	2.243	2.418	2.644	......	......	......	......	......	......
1½	......	......	......	......	......	......	1.141	1.285	1.426	1.564	1.769	1.968	2.163	2.353	2.538	2.777	3.007	......	......	......	......	......
1⅝	......	......	......	......	......	......	1.242	1.398	1.552	1.705	1.929	2.148	2.363	2.573	2.778	3.044	......	......	......	......	......	......
1¾	......	......	......	......	......	......	1.342	1.511	1.679	1.845	2.089	2.329	2.563	2.793	3.018	3.311	3.595	3.870	......	......	......	......
1⅞	......	......	......	......	......	......	1.442	1.625	1.806	1.985	2.249	2.509	2.763	3.013	3.258	3.578	......	......	......	......	......	......
2	......	......	......	......	......	......	1.542	1.738	1.933	2.125	2.409	2.689	2.964	3.234	3.499	3.845	4.182	4.511	4.831	5.143	......	......
2¼	......	......	......	......	......	......	......	......	2.186	2.405	2.730	3.049	3.364	3.674	3.979	4.379	4.770	5.152	5.525	5.891	6.248	6.596
2½	......	......	......	......	......	......	......	......	......	2.686	3.050	3.410	3.765	4.115	4.460	4.913	5.357	5.792	6.220	6.638	7.049	7.450
2¾	......	......	......	......	......	......	......	......	......	2.966	3.371	3.770	4.165	4.555	4.941	5.447	5.944	6.433	6.914	7.386	7.850	8.305
3	......	......	......	......	......	......	......	......	......	3.246	3.691	4.131	4.566	4.996	5.421	5.981	6.532	7.074	7.608	8.133	8.651	9.159
3¼	......	......	......	......	......	......	......	......	......	......	4.011	4.491	4.966	5.436	5.902	6.515	7.119	7.715	8.302	8.881	9.452	10.013
3½	......	......	......	......	......	......	......	......	......	......	4.332	4.852	5.367	5.877	6.382	7.049	7.707	8.356	8.996	9.629	10.25	10.868
3¾	......	......	......	......	......	......	......	......	......	......	......	5.212	5.767	6.317	6.863	7.583	8.294	8.996	9.691	10.38	11.05	11.722
4	......	......	......	......	......	......	......	......	......	......	......	5.573	6.168	6.758	7.344	8.117	8.881	9.637	10.39	11.12	11.85	12.577
4½	......	......	......	......	......	......	......	......	......	......	......	6.293	6.969	7.639	8.305	9.185	10.06	10.92	11.77	12.62	13.46	14.286
5	......	......	......	......	......	......	......	......	......	......	......	7.014	7.770	8.520	9.266	10.25	11.23	12.20	13.16	14.11	15.06	15.994
5¼	......	......	......	......	......	......	......	......	......	......	......	7.375	8.170	8.961	9.747	10.79	11.82	12.84	13.86	14.86	15.86	16.849
5⅜	......	......	......	......	......	......	......	......	......	......	......	7.555	8.370	9.181	9.987	11.05	12.11	13.16	14.20	15.24	16.26	17.276
5½	......	......	......	......	......	......	......	......	......	......	......	7.735	8.571	9.401	10.23	11.32	12.41	13.48	14.55	15.61	16.66	17.703
6	......	......	......	......	......	......	......	......	......	......	......	......	9.372	10.28	11.19	12.39	13.58	14.76	15.94	17.11	18.26	19.412

be made on two additional tubes from the same lot, each of which shall conform to the requirements specified.

Forming Operations

13. Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

Standard Weights

14. The standard weights for tubes of various outside diameters and thicknesses are given in Table I.

NOTE 3.—The weights given in Table I are theoretical and are based on tubes of the exact diameters and wall thicknesses shown. Minimum wall tubes, as called for in these specifications, will weigh from 10 to 15 per cent heavier than those shown depending on the size and wall thickness specified.

Permissible Variations in Dimensions and Weight

15. (*a*) Variations in outside diameter, wall thickness, weight, and length, from those specified, shall not exceed the amounts shown in Table II.

(*b*) The diameter measured at any point on the outer circumference on finished tubes shall not vary more than the amounts shown in Table II.

TABLE II.—PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHTS.

Size, Outside Diameter, in.	Outside Diameter (including out of roundness), in.[a,b]		Wall Thickness, per cent[a, c]								Weight[d] per foot, per cent		Length Cut, in.[e]	
			0.095 in. and under		Over 0.095 to 0.150 in., incl.		Over 0.150 to 0.180 in., inc .		Over 0.180 in.					
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
							HOT-FINISHED TUBES							
4 and under	1/64	1/32	40	0	35	0	33	0	28	0	16	0	3/16	0
Over 4	1/64	3/64	..	..	35	0	33	0	28	0	16	0	3/16	0
							COLD-DRAWN TUBES							
			Over				Under							
Under 1	0.004	0.004	20				0				12	0	1/8	0
1 to 1½, incl	0.006	0.006	20				0				12	0	1/8	0
Over 1½ to under 2	0.008	0.008	22				0				13	0	1/8	0
2 to under 2½	0.010	0.010	22				0				13	0	3/16	0
2½ to under 3	0.012	0.012	22				0				13	0	3/16	0
3 to 4, incl	0.015	0.015	22				0				13	0	3/16	0
Over 4	0.015	0.025	22				0				13	0	3/16	0

[a] The gaging tolerances given apply only to the tubes as rolled or drawn and before swaging, expanding, bending, polishing, or other fabricating operations.

[b] Cold-drawn tubing having a specified wall thickness which is 3 per cent, or less than 3 per cent, of the outside diameter cannot be straightened properly without a certain amount of ovality resulting in the diameter, consequently such tubes, while having an average outside diameter within the permissible variations shown in the table, will require an additional ovality permissible variation of plus or minus 0.5 per cent of the outside diameter.

[c] On tubes 2 in. and over in outside diameter and 0.220 in. in thickness and over the variation in wall thickness in any one cross-section of any one tube shall not exceed plus or minus 10 per cent of the actual average wall of that section. The actual average wall is defined as the average of the thickest and thinnest wall in that section.

[d] The permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. in outside diameter and under, and to lots of 20 tubes or more in sizes over 4 in. in outside diameter.

[e] Permissible variations in length apply to tubes before bending.

Finish

16. Finished tubes shall be reasonably straight and have smooth ends, free from burrs. They shall be free from injurious defects and shall have a workmanlike finish.

Marking

17. (*a*) The name or brand of the manufacturer, the grade of material

from which it is made, whether seamless or lap-welded, and whether steel or iron, together with the hydrostatic pressure in pounds at which it was tested, shall be legibly stenciled on each tube $1\frac{1}{4}$ in. outside diameter and over, provided the length is not under 3 ft.

(*b*) On tubes less than $1\frac{1}{4}$ in. in diameter and on all tubes under 3 ft. in length, the information prescribed in Paragraph (*a*) shall be indicated on a tag securely attached to the bundle or box in which the tubes are shipped.

Inspection

18. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture.

Certification

(*b*) When required, the manufacturer shall furnish the purchaser of each lot of tubes a statement as to the kind of material of which the tubes are made and certifying that the tubes have been tested and have met all the requirements of these specifications.

Rejection

19. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 (*a*) shall be reported to the manufacturer within five working days from the receipt of samples.

(*b*) Tubes which fail in any of the forming operations provided for under Section 13 will be rejected and the manufacturer shall be notified.

Rehearing

20. Samples tested in accordance with Section 4 (*a*) which represent rejected tubes, shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Tentative Specifications for
SEAMLESS STEEL BOILER TUBES FOR HIGH-PRESSURE SERVICE[1]

A.S.T.M. Designation: A 192 – 38 T

ISSUED, 1936; REVISED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. (*a*) These specifications cover seamless steel boiler tubes and superheater tubes $\frac{1}{2}$ in. in outside diameter or larger. Tubes less than 2 in. in outside diameter shall have wall thicknesses of not less than 8 per cent of the outside diameter and in no case less than 0.085 in. Tubes 2 in. and over in outside diameter shall have wall thicknesses of not less than 0.200 in.

(*b*) The diameters and wall thicknesses of tubes covered by these specifications are shown in Table II.

Process

2. The steel shall be a killed steel and shall be made by either or both of the following processes: open-hearth or electric-furnace.

Manufacture

3. (*a*) Tubes shall be made by the seamless process and shall be either hot finished or cold-drawn, as specified.

(*b*) Cold-drawn tubes shall be annealed "dead soft" after the final cold-draw pass. Hot-finished tubes need not be annealed unless specified by the purchaser.

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

Carbon, per cent	0.08 to 0.18
Manganese, per cent	0.30 to 0.60
Phosphorus, max., per cent	0.04
Sulfur, max., per cent	0.045
Silicon, max., per cent	0.25

Check Analysis

5. (*a*) Analyses of two tubes in each lot of 100 lengths, or fraction thereof, may be made by the purchaser. Drillings for analysis shall be taken from several points around each tube selected for analysis. The chemical composition thus determined shall conform to the requirements specified in Section 4.

(*b*) If the analysis of either tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 4.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Revision accepted by Committee E-10 on Standards, August 25, 1938.

Flattening Tests

6. A section of tube $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates, without cracking or showing any flaw, until the distance between the plates is four times the wall thickness.

Flaring Test

7. A section of tube approximately 4 in. in length shall stand being flared with a tool having a 60-deg. included angle until the tube at the mouth of the flare has been expanded to the following percentages, without cracking or showing flaws:

RATIO OF INSIDE DIAMETER TO OUTSIDE DIAMETER[a]	MINIMUM EXPANSION OF INSIDE DIAMETER, PER CENT
0.9	20
0.8	22
0.7	25
0.6	30
0.5	37
0.4	50
0.3	67

[a] In determining the ratio of inside diameter to outside diameter, the inside diameter shall be defined as the actual inside diameter of the material tested.

Hardness Test

8. (*a*) A Brinell test shall show a hardness number not to exceed the following:

	BRINELL HARDNESS NUMBER
Hot-finished tubes	137
Cold-drawn tubes	125

(*b*) The hardness test may be made on the tube near the end or on a specimen cut from the tube, at the option of the manufacturer.

(*c*) In making the Brinell hardness test, reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[3] In the case of tubes with wall thicknesses less than $\frac{3}{8}$ in., a 10-mm. ball with 1500-kg. load, or a 5-mm. ball with 750-kg. load, may be used, at the option of manufacturer.

(*d*) *Alternate.*—The Rockwell hardness test may be used instead of the Brinell test, when desirable, in which case the test shall show a hardness number not to exceed the following:

	ROCKWELL HARDNESS NUMBER
Hot-finished tubes	B77
Cold-drawn tubes	B72

(*e*) In making the Rockwell hardness test, reference should be made to the Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.[4]

TABLE I.—HYDROSTATIC TEST PRESSURE.

SIZE, OUTSIDE DIAMETER, IN.	HYDROSTATIC TEST PRESSURE, PSI.
Under 1	1000
1 to $1\frac{1}{2}$, excl	1500
$1\frac{1}{2}$ to 2 excl	2000
2 and over	2500

Hydrostatic Test

9. Prior to upsetting, swaging, expanding, bending, or other forming operations, each tube shall be tested at the mill to the hydrostatic pressures prescribed in Table I (Note), provided that the fiber stress calculated in accordance with the following formula does not exceed 16,000 psi.:

$$P = \frac{2St}{D}$$

where:

P = the hydrostatic test pressure in pounds per square inch,

S = the allowable fiber stress of 16,000 psi.,

t = the thickness of the tube wall in inches, and

D = the outside diameter of the tube in inches.

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[3] 1936 Book of A.S.T.M. Standards, Part I, p. 817.

[4] 1936 Book of A.S.T.M. Standards, Part I, p. 824.

NOTE.—When requested by the purchaser and so stated in the order, tubes shall be tested to one and one-half times the specified working pressure (where one and one-half the specified working pressure exceeds the test pressures stated in Section 9), provided the fiber stress corresponding to those test pressures does not exceed 16,000 psi., as determined by the above formula.

Test Specimens

10. (*a*) Test specimens required for the flattening and flaring tests under Sections 6 and 7 shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

(*b*) All specimens shall be tested at room temperature.

Number of Tests

11. (*a*) From each lot of 100 tubes, or fraction thereof, four tubes shall be selected for test. From each end of two of these test tubes, the flattening test specified in Section 6 shall be made and from each end of the other two test tubes the flaring test specified in Section 7 shall be made.

(*b*) Five per cent of all tubes shall be selected for the hardness test specified in Section 8, and one Brinell hardness determination shall be made on each of these tubes.

(*c*) Each tube shall be subjected to the hydrostatic test, specified in Section 9.

Retests

12. If the results of any physical tests of any lot do not conform to the requirements specified in Sections 6, 7, and 8, retests may be made on additional tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

Forming Operations

13. Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding and bending operations necessary for application without developing defects.

Standard Weights

14. The standard weights for tubes of various outside diameters and thicknesses shall conform to the requirements prescribed in Table II.

Permissible Variations in Dimensions and Weight

15. Variations in outside diameter, wall thickness, weight, and length, from those specified, shall not exceed the amounts shown in Table III.

Finish

16. Finished tubes shall be reasonably straight and have smooth ends, free from burrs. They shall be free from injurious defects and have a workmanlike finish. Minor defects may be removed by grinding provided the wall thicknesses and the outside diameter are not decreased to less than that permitted in Section 15.

Marking

17. The name or brand of the manufacturer, the words Seamless Steel, A.S.T.M. Specification A 192 – 38 T, the hydrostatic test pressure in pounds per square inch, and whether hot finished or cold drawn, shall be legibly stenciled on each tube.

Inspection

18. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the ma-

TABLE II.—STANDARD WEIGHTS OF SEAMLESS BOILER AND SUPERHEATER TUBES, INCLUDING SAFE ENDS, ARCH, AND STAY TUBES.

NOTE.—The weights given in this table are theoretical and are based on tubes having a perfect outside diameter, inside diameter, and wall thickness. Minimum wall tubes as called for in these specifications, will weigh from 10 to 15 per cent heavier than those shown, depending on the size and wall thickness specified.

Wall Thickness, in.	0.085	0.095	0.105	0.120	0.135	0.150	0.165	0.180	0.200	0.220	0.240	0.260	0.280	0.300	0.320	0.340	0.360
Wall Thickness, nearest B.w.g. No.	14+	13	12−	11	10+	9+	8	7	6−	5	4+	3+	2−	1	0	0	0
Size, Outside Diameter, in.	Weight, lb. per ft. of length																
1/2	0.377	0.410	0.443	0.487	0.526	0.561	...	...	...	...	...	...	...	...	...	...	...
5/8	0.490	0.538	0.583	0.647	0.707	0.761	0.811	...	...	...	...	...	...	...	...	...	...
11/16	0.547	0.602	0.654	0.728	0.797	0.862	0.922	0.977	...	...	...	...	...	...	...	...	...
3/4	0.604	0.665	0.723	0.807	0.887	0.961	1.031	1.096	1.175	...	...	...	...	...	...	...	...
13/16	0.661	0.729	0.794	0.888	0.978	1.062	1.142	1.217	1.309	1.393	...	...	...	...	...	...	...
7/8	0.717	0.791	0.864	0.968	1.067	1.161	1.251	1.336	1.442	1.539	1.628	...	...	...	...	...	...
15/16	0.774	0.855	0.934	1.048	1.158	1.262	1.362	1.457	1.576	1.687	1.789	1.883	...	...	...	...	...
1	0.831	0.918	1.004	1.128	1.247	1.362	1.471	1.576	1.709	1.833	1.948	2.055	2.153	...	...	...	...
1 1/8	...	1.045	1.144	1.288	1.427	1.562	1.692	1.817	1.976	2.126	2.268	2.402	2.527	2.643	...	...	...
1 3/16	...	1.109	1.214	1.369	1.518	1.663	1.803	1.938	2.110	2.274	2.427	2.574	2.712	2.845	2.963	...	...
1 1/4	...	...	1.284	1.448	1.608	1.762	1.912	2.057	2.243	2.420	2.589	2.749	2.901	3.044	3.178	3.304	...
1 3/8	...	...	...	1.608	1.788	1:962	2.132	2.297	2.510	2.714	2.909	3.096	3.274	3.444	3.606	3.758	3.902
1 7/16	...	...	...	1.689	1.879	2.063	2.243	2.418	2.644	2.862	3.071	3.271	3.463	3.646	3.821	3.987	4.145
1 1/2	...	...	...	1.769	1.968	2.163	2.353	2.538	2.777	3.007	3.230	3.443	3.648	3.845	4.033	4.212	4.383
1 5/8	...	...	...	...	2.148	2.363	2.573	2.778	3.044	3.301	3.550	3.790	4.022	4.245	4.460	4.666	4.864
1 3/4	...	...	...	...	...	2.563	2.793	3.018	3.311	3.595	3.870	4.137	4.396	4.646	4.887	5.120	5.344
1 7/8	...	...	...	...	...	2.763	3.013	3.258	3.578	3.889	4.191	4.485	4.770	5.046	5.314	5.574	5.825
2	...	...	...	...	...	...	...	...	3.845	4.182	4.511	4.831	5.143	5.447	5.742	6.028	6.305
2 1/4	...	...	...	...	...	...	...	...	4.379	4.770	5.152	5.525	5.891	6.248	6.596	6.936	7.267
2 1/2	...	...	...	...	...	...	...	...	4.913	5.357	5.792	6.220	6.638	7.049	7.450	7.843	8.228
2 3/4	...	...	...	...	...	...	...	...	5.447	5.944	6.433	6.914	7.386	7.850	8.306	8.751	9.189
3	...	...	...	...	...	...	...	...	5.981	6.532	7.074	7.608	8.133	8.651	9.159	9.659	10.15
3 1/4	...	...	...	...	...	...	...	...	6.515	7.119	7.715	8.302	8.881	9.452	10.01	10.57	11.11
3 1/2	...	...	...	...	...	...	...	...	7.049	7.707	8.356	8.996	9.629	10.25	10.87	11.48	12.07
3 3/4	...	...	...	...	...	...	...	...	7.583	8.294	8.996	9.691	10.38	11.05	11.72	12.38	13.03
4	...	...	...	...	...	...	...	...	...	8.881	9.237	10.39	11.12	11.85	12.58	13.29	14.00
4 1/2	...	...	...	...	...	...	...	...	...	...	10.92	11.77	12.62	13.46	14.29	15.11	15.92
5	...	...	...	...	...	...	...	...	...	...	...	...	14.11	15.06	15.99	16.92	17.84
5 1/4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16.85	17.83	18.80
5 3/8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	18.28	19.28
5 1/2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19.76

TABLE II.—(*Continued*).

Wall Thickness, in.	0.380	0.400	0.420	0.440	0.460	0.480	0.500	0.531	0.563	0.594	0.625	0.688	0.750	0.875	1.000
Size, Outside Diameter, in.	Weight, lb. per ft. of length														
1 7/16	4.294														
1 1/2	4.545	4.699													
1 5/8	5.053	5.233	5.405												
1 3/4	5.560	5.767	5.966	6.156											
1 7/8	6.067	6.301	6.527	6.743	6.952	7.151									
2	6.575	6.835	7.087	7.331	7.566	7.792	8.010								
2 1/4	7.589	7.903	8.209	8.506	8.794	9.074	9.345								
2 1/2	8.604	8.971	9.330	9.680	10.02	10.36	10.68								
2 3/4	9.618	10.04	10.46	10.86	11.25	11.64	12.02								
3	10.63	11.11	11.57	12.03	12.48	12.92	13.35								
3 1/4	11.65	12.18	12.69	13.21	13.71	14.20	14.69								
3 1/2	12.66	13.24	13.82	14.38	14.94	15.48	16.02	16.84							
3 3/4	13.68	14.31	14.94	15.55	16.16	16.76	17.36	18.26	19.16						
4	14.69	15.38	16.06	16.73	17.39	18.05	18.69	19.67	20.67	21.61					
4 1/2	16.72	17.52	18.30	19.08	19.85	20.61	21.36	22.51	23.67	24.78	25.87				
5	18.75	19.65	20.54	21.43	22.30	23.17	24.03	25.34	26.68	27.95	29.20	31.68			
5 1/4	19.76	20.72	21.67	22.60	23.53	24.45	25.37	26.76	28.18	29.54	30.87	33.52	36.05		
5 3/8	20.27	21.25	22.23	23.19	24.15	25.09	26.03	27.47	28.93	30.33	31.71	34.44	37.05	42.05	46.73
5 1/2	20.79	21.79	22.83	23.78	24.76	25.76	26.70	28.18	29.69	31.12	32.54	35.36	38.05	43.22	48.06
6		23.92	25.02	26.13	27.21	28.30	29.37	31.02	32.69	34.30	35.88	39.03	42.05	47.89	53.40
6 1/4			26.15	27.31	28.45	29.58	30.71	32.43	34.20	35.88	37.55	40.87	44.08	50.23	56.07
6 1/2				28.48	29.67	30.86	32.04	33.85	35.70	37.47	38.22	42.71	46.06	52.57	58.74
7					32.13	33.43	34.76	36.69	38.70	40.64	42.55	46.38	50.06	57.24	64.08

terial is being furnished in accordance with these specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture.

Certification

(*b*) When required, the manufacturer shall furnish the purchaser of each lot of tubes a statement as to the kind of material of which the tubes are made and certifying that the tubes have been tested and have met all the requirements of these specifications.

TABLE III.—PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHTS.

Size, Outside Diameter, in.	Outside Diameter (including out of roundness), in.[a,b]		Wall Thickness, per cent[a, c]								Weight[d] per foot, per cent		Length Cut, in.[e]	
			0.095 in. and under		Over 0.095 to 0.150 in., incl.		Over 0.150 to 0.180 in., incl.		Over 0.180 in.					
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
HOT-FINISHED TUBES														
4 and under	1/64	1/32	40	0	35	0	33	0	28	0	16	0	3/16	0
Over 4	1/64	3/64	..	..	35	0	33	0	28	0	16	0	3/16	0
COLD-DRAWN TUBES														
			Over				Under							
Under 1	0.004	0.004	20				0				12	0	1/8	0
1 to 1½, incl	0.006	0.006	20				0				12	0	1/8	0
Over 1½ to under 2	0.008	0.008	22				0				13	0	1/8	0
2 to under 2½	0.010	0.010	22				0				13	0	3/16	0
2½ to under 3	0.012	0.012	22				0				13	0	3/16	0
3 to 4, incl	0.015	0.015	22				0				13	0	3/16	0
Over 4	0.015	0.025	22				0				13	0	3/16	0

[a] The gaging tolerances given apply only to the tubes as rolled or drawn and before swaging, expanding, bending polishing, or other fabricating operations.

[b] Cold-drawn tubing having a specified wall thickness which is 3 per cent, or less than 3 per cent, of the outside diameter cannot be straightened properly without a certain amount of ovality resulting in the diameter, consequently such tubes, while having an average outside diameter within the permissible variations shown in the table, will require an additional ovality permissible variation of plus or minus 0.5 per cent of the outside diameter.

[c] On tubes 2 in. and over in outside diameter and 0.220 in. in thickness and over the variation in wall thickness in any one cross-section of any one tube shall not exceed plus or minus 10 per cent of the actual average wall of that section. The actual average wall is defined as the average of the thickest and thinnest wall in that section.

[d] The permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. in outside diameter and under, and to lots of 20 tubes or more in sizes over 4 in. in outside diameter.

[e] Permissible variations in length apply to tubes before bending.

Rejection

19. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 (*a*) shall be reported to the manufacturer within five working days from the receipt of samples.

(*b*) Tubes which fail in any of the forming operations provided for under Section 13 will be rejected and the manufacturer shall be notified.

Rehearing

20. Samples tested in accordance with Section 5 (*a*) which represent rejected tubes, shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTE

NOTE.—For purposes of design, the following tensile properties may be assumed:

Tensile strength, min., psi	47 000
Yield point, min., psi	26 000
Elongation in 2 in., min., per cent	35

TO BE DESIGNATED
A.S.M.E. BOILER CONSTRUCTION CODE
SPECIFICATION No.: S-49

Tentative Specifications for
MEDIUM-CARBON SEAMLESS STEEL BOILER AND SUPERHEATER TUBES[1]

A.S.T.M. Designation: A 210 - 38 T

ISSUED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. (*a*) These specifications cover seamless steel boiler tubes and boiler flues, including safe ends,[3] arch and stay tubes, and superheater tubes.

(*b*) The diameters and wall thicknesses of tubes covered by the specifications are listed in Table II.

Process

2. The steel shall be a killed steel and shall be made by either or both of the following processes: open-hearth or electric-furnace.

Manufacture

3. (*a*) Tubes shall be made by the seamless process and shall be either hot finished or cold drawn, as specified.

(*b*) Hot-finished tubes shall be annealed by heating to at least 1300 F. (690 C.). Cold-drawn tubes shall be annealed after the final cold-draw pass.

Chemical Composition

4. (*a*) The steel shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.35
Manganese, max., per cent	0.80
Phosphorus, max., per cent	0.04
Sulfur, max., per cent	0.045
Silicon, min., per cent	0.10

(*b*) The manufacturer shall submit a report showing the ladle analysis of each melt of steel from which the tubes have been made, or a report of check analysis as provided in Section 5.

Check Analysis

5. (*a*) At the request of the purchaser, analyses as specified in the following table shall be made by the manufacturer on samples of finished tubing selected at random and shall conform to the requirements prescribed in Section 4 (*a*). Drillings for analysis shall be taken from several points around each tube selected for analysis.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These specifications are in effect a revision of and replace Grade C of the former Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 - 36), which standard was accordingly discontinued in 1938.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

[3] This grade is not suitable for safe ending by forge welding.

SIZE OF TUBE	NUMBER OF SAMPLES SELECTED
2 in. and over in diameter and 0.200 in. and over in wall thickness	2 from each lot of 100 tubes, or fraction thereof
Less than 2 in. in diameter or any size less than 0.200 in. in wall thickness	2 from each lot of 250 tubes, or fraction thereof

(*b*) If the analysis of either tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 4 (*a*).

Tensile Properties

6. (*a*) The material shall conform to the following minimum requirements as to tensile properties at room temperature:

Tensile strength, min., psi	60 000
Yield point, min., psi	37 000
Elongation in 2 in., min., per cent	25

(*b*) The yield point shall be determined by the drop of the beam or halt in the gate of the testing machine, or by the use of dividers or other approved method, at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. When a definite yield point is not exhibited, the yield strength corresponding to a limited permanent offset of 0.2 per cent of the gage length of the specimen shall be reported instead. The "offset method" of determining yield strength as described in the Standard Method of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[4] shall be followed. The tensile strength shall be determined at a cross-head speed not to exceed $1\frac{1}{2}$ in. per min.

Flattening Test

7. (*a*) For tubes having wall thicknesses[5] not exceeding 10 per cent of their outside diameters, a section not less than $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates until the distance between the plates is five times the wall thickness, without cracking or showing flaws.

(*b*) For tubes having wall thicknesses[5] exceeding 10 per cent of their outside diameters, a section not less than $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates until the distance between the plates is seven times the wall thickness, without cracking or showing flaws.

Flaring Test

8. A section of tube approximately 4 in. in length shall stand being flared with a tool having a 60-deg. included angle until the tube at the mouth of the flare has been expanded to the following percentages, without cracking or showing flaws:

RATIO OF INSIDE DIAMETER TO OUTSIDE DIAMETER[a]	MINIMUM EXPANSION OF INSIDE DIAMETER, PER CENT
0.9	20
0.8	22
0.7	25
0.6	30
0.5	37
0.4	50
0.3	67

[a] In determining the ratio of inside diameter to outside diameter, the inside diameter shall be defined as the actual inside diameter of the material tested.

Hardness Test

9. (*a*) A Brinell test shall show a hardness number not to exceed 143.

(*b*) The hardness test may be made on the tube near the end or on a specimen cut from the tube, at the option of the manufacturer.

(*c*) In making the Brinell hardness test, reference should be made to the Standard Method of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[6] In the case of tubes with wall thicknesses less than $\frac{3}{8}$ in., a 10-mm. ball with 1500-kg. load, or a 5-mm. ball with 750-kg. load, may be used, at the option of manufacturer.

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[4] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

[5] The term wall thickness shall be defined as the actual mean wall of the material tested.

[6] 1936 Book of A.S.T.M. Standards, Part I, p. 817.

(*d*) *Alternate.*—The Rockwell hardness test may be used instead of the Brinell test, when desirable, in which case the test shall show a hardness number not to exceed B 79.

(*e*) In making the Rockwell hardness test, references should be made to the Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.[7] The test shall be made on the inside surface of the tube to avoid erratic results due to spring.

TABLE I.—HYDROSTATIC TEST PRESSURE.

SIZE, OUTSIDE DIAMETER, IN.	HYDROSTATIC TEST PRESSURE, PSI.
Under 1	1000
1 to 1½, excl.	1500
1½ to 2, excl.	2000
2 and over	2500

Hydrostatic Test

10. Prior to upsetting, swaging, expanding, bending, or other forming operations, each tube shall be tested at the mill to the hydrostatic pressures prescribed in Table I (Note), provided that the fiber stress calculated according to the following formula does not exceed 24,000 psi:

$$P = \frac{2\,St}{D}$$

where:

P = the hydrostatic test pressure in pounds per square inch,

S = the allowable fiber stress of 24,000 psi.,

t = the thickness of the tube wall in inches, and

D = the outside diameter of the tube in inches.

NOTE.—When requested by the purchaser and so stated in the order, tubes shall be tested to one and one-half times the specified working pressure (where one and one-half the specified working pressure exceeds the test pressures stated in Section 10), provided the fiber stress corresponding to those test pressures does not exceed 24,000 psi. as determined by the above formula.

Test Specimens

11. (*a*) Test specimens required for the flattening and flaring tests under Sections 7 and 8 shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

(*b*) Tension tests, if desirable and practicable, may be made on full sections of the tubes up to the capacity of the testing machine. For larger size tubes, the tension specimen shall consist of a strip cut longitudinally from the tube and not flattened between gage marks. The sides of the specimen shall be parallel between gage marks; the width, irrespective of the thickness, shall be 1 in.; the gage length shall be 2 in.

(*c*) On tubes furnished with upset, swaged, or otherwise formed ends, the hardness test specified in Section 9 shall be made on the ends of the tubes after forming operation.

(*d*) All specimens shall be tested at room temperature.

Number of Tests

12. (*a*) From each group of 100 finished tubes, or fraction thereof, two tubes shall be selected at random for the tension test specified in Section 6.

(*b*) From each heat-treated lot of finished tubes, two tubes shall be selected at random for purpose of tests. The flattening test specified in Section 7 shall be made on each end of one of these tubes and the flaring test specified in

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[7] 1936 Book of A.S.T.M. Standards, Part I, p. 824.

TABLE II.—STANDARD WEIGHTS OF MEDIUM-CARBON SEAMLESS STEEL BOILER AND SUPERHEATER TUBES

NOTE.—The weights given in Table I are theoretical and are based on tubes having a perfect outside diameter, inside diameter, and wall thickness. Minimum wall tubes, as called for in these specifications, will weigh from 10 to 15 per cent heavier than those shown, depending on the size and wall thickness specified.

Wall Thickness, in	0.035	0.040	0.045	0.050	0.055	0.065	0.075	0.085	0.095	0.105	0.120	0.135	0.150	0.165	0.180	0.200
Wall Thickness, nearest B.w.g No.	20	19–	19+	18+	17–	16	15+	14+	13	12–	11	10+	9+	8	7	6–
Size, Outside Diameter, in.	Weight, lb. per ft. of length															
1/2	0.1738	0.1965	0.2187	0.2403	0.2614	0.3020	0.3404	0.3767	0.4109	0.4430	0.487	0.526	0.561	......	......	......
5/8	......	......	0.2787	0.3071	0.3348	0.3888	0.4406	0.4902	0.5377	0.5831	0.647	0.707	0.761	0.811	......	......
11/16	......	......	0.3090	0.3407	0.3718	0.4325	0.4910	0.5474	0.6017	0.6538	0.7279	0.797	0.862	0.922	0.977	......
3/4	......	......	0.3388	0.3738	0.4082	0.4755	0.5407	0.6037	0.6646	0.7233	0.8074	0.8867	0.961	1.031	1.096	1.175
13/16	......	......	......	0.4074	0.4452	0.5193	0.5911	0.6609	0.7285	0.7940	0.8881	0.9775	1.062	1.142	1.217	1.309
7/8	......	......	......	0.4406	0.4817	0.5623	0.6408	0.7172	0.7914	0.8635	0.9676	1.067	1.161	1.251	1.336	1.442
15/16	......	......	......	......	0.5187	0.6060	0.6913	0.7744	0.8553	0.9341	1.048	1.158	1.262	1.362	1.457	1.576
1	......	......	......	......	0.5551	0.6491	0.7409	0.8306	0.9182	1.004	1.128	1.247	1.362	1.471	1.576	1.709
1 1/8	......	......	......	......	0.6285	0.7359	0.8411	0.9441	1.045	1.144	1.288	1.427	1.562	1.692	1.817	1.976
1 3/16	......	......	......	......	......	0.7796	0.8915	1.001	1.109	1.214	1.369	1.518	1.663	1.803	1.938	2.110
1 1/4	......	......	......	......	......	0.8226	0.9412	1.058	1.172	1.284	1.448	1.608	1.762	1.912	2.057	2.243
1 3/8	......	......	......	......	......	0.9094	1.041	1.171	1.299	1.424	1.608	1.788	1.962	2.132	2.297	2.510
1 7/16	......	......	......	......	......	......	1.092	1.228	1.363	1.495	1.689	1.879	2.063	2.243	2.418	2.644
1 1/2	......	......	......	......	......	......	1.141	1.285	1.426	1.564	1.769	1.968	2.163	2.353	2.538	2.777
1 5/8	......	......	......	......	......	......	1.242	1.398	1.552	1.705	1.929	2.148	2.363	2.573	2.778	3.044
1 3/4	......	......	......	......	......	......	1.342	1.511	1.679	1.845	2.089	2.329	2.563	2.793	3.018	3.311
1 7/8	......	......	......	......	......	......	1.442	1.625	1.806	1.985	2.249	2.509	2.763	3.013	3.258	3.578
2	......	......	......	......	......	......	1.542	1.738	1.933	2.125	2.409	2.689	2.964	3.234	3.499	3.845
2 1/4	......	......	......	......	......	......	......	......	2.186	2.405	2.730	3.049	3.364	3.674	3.979	4.379
2 1/2	......	......	......	......	......	......	......	......	......	2.686	3.050	3.410	3.765	4.115	4.460	4.913
2 3/4	......	......	......	......	......	......	......	......	......	2.966	3.371	3.770	4.165	4.555	4.941	5.477
3	......	......	......	......	......	......	......	......	......	3.246	3.691	4.131	4.566	4.996	5.421	5.981
3 1/4	......	......	......	......	......	......	......	......	......	......	4.011	4.491	4.966	5.436	5.902	6.515
3 1/2	......	......	......	......	......	......	......	......	......	......	4.332	4.852	5.367	5.877	6.382	7.049
3 3/4	......	......	......	......	......	......	......	......	......	......	......	5.212	5.767	6.317	6.863	7.583
4	......	......	......	......	......	......	......	......	......	......	......	5.573	6.168	6.758	7.344	8.117
4 1/2	......	......	......	......	......	......	......	......	......	......	......	6.293	6.969	7.639	8.305	9.185
5	......	......	......	......	......	......	......	......	......	......	......	7.014	7.770	8.520	9.266	10.25

Wall Thickness, in.	0.220	0.240	0.260	0.280	0.300	0.320	0.340	0.360	0.380	0.400	0.420	0.440	0.460	0.480	0.500
Wall Thickness, nearest B.w.g No.	5	4+	3+	2–	1	0	0	0	00	00	000	000	000	000	000
Size, Outside Diameter, in.	Weight, lb. per ft. of length														
13/16	1.393	......	......	......	......	......	......	......	......	......	......	......	......	......	......
7/8	1.539	1.628	......	......	......	......	......	......	......	......	......	......	......	......	......
15/16	1.687	1.789	1.883	......	......	......	......	......	......	......	......	......	......	......	......
1	1.833	1.948	2.055	2.153	......	......	......	......	......	......	......	......	......	......	......
1 1/8	2.126	2.268	2.402	2.527	2.643	......	......	......	......	......	......	......	......	......	......
1 3/16	2.274	2.427	2.574	2.712	2.845	2.963	......	......	......	......	......	......	......	......	......
1 1/4	2.420	2.589	2.749	2.901	3.044	3.178	3.304	......	......	......	......	......	......	......	......
1 3/8	2.714	2.909	3.096	3.274	3.444	3.606	3.758	3.902	......	......	......	......	......	......	......
1 7/16	2.862	3.071	3.271	3.463	3.646	3.821	3.987	4.145	4.294	......	......	......	......	......	......
1 1/2	3.007	3.230	3.443	3.648	3.845	4.033	4.212	4.383	4.545	4.699	......	......	......	......	......
1 5/8	3.301	3.550	3.790	4.022	4.245	4.460	4.666	4.864	5.053	5.233	5.405	......	......	......	......
1 3/4	3.595	3.870	4.137	4.396	4.646	4.887	5.120	5.344	5.560	5.767	5.966	6.156	......	......	......
1 7/8	3.889	4.191	4.485	4.770	5.046	5.314	5.574	5.825	6.067	6.301	6.527	6.743	6.952	7.151	......
2	4.182	4.511	4.831	5.143	5.447	5.742	6.028	6.305	6.575	6.835	7.087	7.331	7.566	7.792	8.010
2 1/4	4.770	5.152	5.525	5.891	6.248	6.596	6.936	7.267	7.589	7.903	8.209	8.506	8.794	9.074	9.345
2 1/2	5.357	5.792	6.220	6.638	7.049	7.450	7.843	8.228	8.604	8.971	9.330	9.680	10.02	10.36	10.68
2 3/4	5.944	6.433	6.914	7.386	7.850	8.305	8.751	9.189	9.618	10.04	10.46	10.86	11.25	11.64	12.02
3	6.532	7.074	7.608	8.133	8.651	9.159	9.659	10.15	10.63	11.11	11.57	12.03	12.48	12.92	13.35
3 1/4	7.119	7.715	8.302	8.881	9.452	10.013	10.57	11.11	11.65	12.18	12.69	13.21	13.71	14.20	14.69
3 1/2	7.707	8.356	8.996	9.629	10.25	10.868	11.48	12.07	12.66	13.24	13.82	14.38	14.94	15.48	16.02
3 3/4	8.294	8.996	9.691	10.38	11.05	11.722	12.38	13.03	13.68	14.31	14.94	15.55	16.16	16.76	17.36
4	8.881	9.637	10.39	11.12	11.85	12.577	13.29	14.00	14.69	15.38	16.06	16.73	17.39	18.05	18.69
4 1/2	10.06	10.92	11.77	12.62	13.46	14.286	15.11	15.92	16.72	17.52	18.30	19.08	19.85	20.61	21.36
5	11.23	12.20	13.16	14.11	15.06	15.994	16.92	17.84	18.75	19.65	20.54	21.43	22.30	23.17	24.03

Section 8 shall be made on each end of the remaining tube. For the purpose of calculating the number of tests on tubes heat treated by the continuous process, the number of tubes in a heat-treated lot shall be determined from the size of the tubes as follows:

SIZE OF TUBE	SIZE OF LOT
2 in. and over in diameter and 0.200 in. and over in wall thickness	not more than 50 tubes
Less than 2 in. but over 1 in. in diameter or over 1 in. in diameter and under 0.200 in. in wall thickness	not more than 75 tubes
1 in. or less in diameter	not more than 125 tubes

(*c*) Five per cent of all tubes shall be selected for the hardness tests, specified in Section 9 and one Brinell or one or more Rockwell tests shall be made on each of these tubes.

(*d*) Each tube shall be subjected to the hydrostatic test, specified in Section 10.

TABLE III.—PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHT.

Size, Outside Diameter, in.	Outside Diameter (including out of roundness), in.[a,b]		Wall Thickness, per cent[a, c]								Weight[d] per foot, per cent		Length Cut, in.[e]	
			0.095 in. and under		Over 0.095 to 0.150 in., incl.		Over 0.150 to 0.180 in., incl.		Over 0.180 in.					
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
HOT-FINISHED TUBES														
4 and under	1/64	1/32	40	0	35	0	33	0	28	0	16	0	3/16	0
Over 4	1/64	3/64	..	..	35	0	33	0	28	0	16	0	3/16	0
COLD-DRAWN TUBES														
			Over				Under							
Under 1	0.004	0.004	20				0				12	0	1/8	0
1 to 1½, incl	0.006	0.006	20				0				12	0	1/8	0
Over 1½ to under 2	0.008	0.008	22				0				13	0	1/8	0
2 to under 2½	0.010	0.010	22				0				13	0	3/16	0
2½ to under 3	0.012	0.012	22				0				13	0	3/16	0
3 to 4, incl	0.015	0.015	22				0				13	0	3/16	0
Over 4	0.015	0.025	22								13	0	3/16	0

[a] The gaging tolerances given apply only to the tubes as rolled or drawn and before swaging, expanding, bending polishing, or other fabricating operations.

[b] Cold-drawn tubing having a specified wall thickness which is 3 per cent, or less than 3 per cent, of the outside diameter cannot be straightened properly without a certain amount of ovality resulting in the diameter, consequently such tubes, while having an average outside diameter within the permissible variations shown in the table, will require an additional ovality permissible variation of plus or minus 0.5 per cent of the outside diameter.

[c] On tubes 2 in. and over in outside diameter and 0.220 in. in thickness and over the variation in wall thickness in any one cross-section of any one tube shall not exceed plus or minus 10 per cent of the actual average wall of that section. The actual average wall is defined as the average of the thickest and thinnest wall in that section.

[d] The permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. in outside diameter and under and to lots of 20 tubes or more in sizes over 4 in. in outside diameter.

[e] Permissible variations in length apply to tubes before bending.

Retest

13. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 6, 7, 8, and 9, retests may be made on additional tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

(*b*) If any tension test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted. If the elongation of any tension test specimen is less than that specified, and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retreatment

14. If individual tubes or tubes selected to represent any group or lot fail

to meet the test requirements specified in Sections 6, 7, 8, and 9, the individual tubes or group or lot represented may be retreated and resubmitted for test. Only two reheat treatments will be permitted.

Forming Operations

15. Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

Standard Weights

16. The standard weights for tubes of various outside diameters and wall thicknesses are given in Table II.

Permissible Variations in Dimensions and Weight

17. Variations in outside diameter, wall thickness, weight, and length, from those specified, shall not exceed the amount shown in Table III.

Finish

18. Finished tubes shall be reasonably straight and have smooth ends, free from burrs. They shall be free from injurious defects and have a workman like finish. Minor defects may be removed by grinding provided the wall thicknesses are not decreased to less than that permitted in Section 17.

Marking

19. (*a*) The name or brand of the manufacturer, the grade of material from which it is made (Medium Carbon), A.S.T.M. Specification A 210 – 38 T, together with hydrostatic test pressure in pounds per square inch, and whether hot finish or cold drawn, shall be legibly stenciled on each tube $1\frac{1}{4}$ in. in outside diameter and over, provided the length is not under 3 ft.

(*b*) On tubes less than $1\frac{1}{4}$ in. in diameter and on all tubes under 3 ft. in length, the information prescribed in Paragraph (*a*) shall be indicated on a tag securely attached to the bundle or box in which the tubes are to be shipped.

Inspection

20. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture.

Certification

(*b*) When required, the manufacturer shall furnish the purchaser of each lot of tubes a statement as to the kind of material of which the tubes are made and certifying that the tubes have been tested and have met all the requirements of these specifications.

Pickling or Shot Blasting

(*c*) If pickling or shot blasting, or both are required, this shall be specifically stated in the order and shall be done at the purchaser's expense.

Rejection

21. (*a*) When inspection at the place of manufacture has been waived, any rejection based on tests made in accordance with Section 5 (*a*) shall be reported, by the purchaser, within five working days from receipt of samples.

(*b*) Tubes which fail in any of the forming operations provided for under

Section 15 will be rejected and the manufacturer shall be notified.

Rehearing

22. Samples tested in accordance with Section 5 (*a*) or 5 (*b*) which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TO BE DESIGNATED
A.S.M.E. BOILER CONSTRUCTION CODE
SPECIFICATION No.: S-48

Tentative Specifications for

SEAMLESS CARBON-MOLYBDENUM ALLOY-STEEL BOILER AND SUPERHEATER TUBES[1]

A.S.T.M. Designation: A 209 – 38 T

ISSUED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. (*a*) These specifications cover two grades of seamless carbon-molybdenum alloy-steel boiler and superheater tubes.

(*b*) The diameters and wall thicknesses of tubes covered by these specifications are listed in Table II.

(*c*) The grade desired shall be specified in the purchase order.

Process

2. The steel shall be a killed steel and shall be made by either or both of the following processes: open-hearth or electric-furnace.

Manufacture

3. (*a*) Tubes shall be made by the seamless process and shall be either hot finished or cold drawn, as specified.

(*b*) Hot-finished tubes shall be annealed or normalized and drawn. Cold-drawn tubes shall be annealed after the final cold-draw pass.

Chemical Composition

4. (*a*) The steel shall conform to the following requirements as to chemical composition:

	GRADE T1	GRADE T1a
Carbon, per cent	0.10 to 0.20	0.15 to 0.25
Manganese, per cent	0.30 to 0.60	0.30 to 0.60
Phosphorus, max., per cent	0.04	0.04
Sulfur, max., per cent	0.05	0.05
Silicon, per cent	0.10 to 0.50	0.10 to 0.50
Molybdenum, per cent	0.45 to 0.65	0.45 to 0.65

(*b*) The manufacturer shall submit a report showing the ladle analysis of each melt of steel from which the tubes have been made, or a report of check analysis as provided in Section 5.

Check Analysis

5. (*a*) At the request of the purchaser, analyses as specified in the following table shall be made by the manufacturer on samples of finished tubing selected at random and shall conform to the requirements prescribed in Section 4 (*a*). Drillings for analysis shall be taken from several points around each tube selected for analysis.

SIZE OF TUBE	NUMBER OF SAMPLES SELECTED
2 in. and over in diameter and 0.200 in. and over in wall thickness	2 from each lot of 100 tubes, or fraction thereof
Less than 2 in. in diameter or any size less than 0.200 in. in wall thickness	2 from each lot of 250 tubes, or fraction thereof

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

(*b*) If the analysis of either tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 4 (*a*).

Tensile Properties

6. (*a*) The material shall conform to the following minimum requirements as to tensile properties at room temperature:

	GRADE T1	GRADE T1a
Tensile strength, min., psi	55 000	60 000
Yield point, min., psi	30 000	32 000
Elongation in 2 in., min., per cent	30	30

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by the use of dividers or other approved method, at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. When a definite yield point is not exhibited, the yield strength corresponding to a limited permanent offset of 0.2 per cent of the gage length of the specimen shall be reported instead. The "offset method" of determining yield strength as described in the Standard Method of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[3] shall be followed. The tensile strength shall be determined at a cross-head speed not to exceed $1\frac{1}{2}$ in. per min.

Flattening Test

7. (*a*) For tubes having wall thicknesses[4] not exceeding 10 per cent of their outside diameters, a section not less than $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates until the distance between the plates is three times the wall thickness, without cracking or showing flaws.

(*b*) For tubes having wall thicknesses[4] exceeding 10 per cent of their outside diameters, a section not less than $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates until the distance between the plates is four times the wall thickness, without cracking or showing flaws.

Flaring Test

8. A section of tube approximately 4 in. in length shall stand being flared with a tool having a 60-deg. included angle until the tube at the mouth of the flare has been expanded to the following percentages, without cracking or showing flaws:

RATIO OF INSIDE DIAMETER TO OUTSIDE DIAMETER[a]	MINIMUM EXPANSION OF INSIDE DIAMETER, PER CENT
0.9	20
0.8	22
0.7	25
0.6	30
0.5	37
0.4	50
0.3	67

[a] In determining the ratio of inside diameter to outside diameter, the inside diameter shall be defined as the actual inside diameter of the material tested.

Hardness Test

9. (*a*) A Brinell test shall show a hardness number not to exceed the following:

	BRINELL HARDNESS NUMBER
Grade T1	137
Grade T1a	143

(*b*) The hardness test may be made on the tube near the end or on a specimen cut from the tube, at the option of the manufacturer.

(*c*) In making the Brinell hardness test, reference should be made to the Standard Method of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[5] In the case of tubes with wall thicknesses less than $\frac{3}{8}$ in., a 10-mm. ball with 1500-kg. load, or a 5-mm. ball with 750-kg. load, may be used, at the option of the manufacturer.

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[3] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

[4] The term wall thickness shall be defined as the actual mean wall of the material tested.

[5] 1936 Book of A.S.T.M. Standards, Part I, p. 817.

(*d*) *Alternate.*—The Rockwell hardness test may be used instead of the Brinell test, when desirable, in which case the test shall show a hardness number not to exceed the following:

	ROCKWELL HARDNESS NUMBER
Grade T1	B77
Grade T1a	B79

(*e*) In making the Rockwell hardness test, reference should be made to the Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.[6]

TABLE I.—HYDROSTATIC TEST PRESSURE.

SIZE, OUTSIDE DIAMETER, IN.	HYDROSTATIC TEST PRESSURE, PSI.
Under 1	1000
1 to $1\frac{1}{2}$, excl	1500
$1\frac{1}{2}$ to 2, excl	2000
2 and over	2500

Hydrostatic Test

10. Prior to upsetting, swaging, expanding, bending, or other forming operations, each tube shall be tested at the mill to the hydrostatic pressures prescribed in Table I (Note), provided that the fiber stress calculated according to the following formula does not exceed 24,000 psi.:

$$P = \frac{2\,St}{D}$$

where:

P = the hydrostatic test pressure in pounds per square inch,

S = the allowable fiber stress of 24,000 psi.,

t = the thickness of the tube wall in inches, and

D = the outside diameter of the tube in inches.

NOTE.—When requested by the purchaser and so stated in the order, tubes shall be tested to one and one-half times the specified working pressure (where one and one-half the specified working pressure exceeds the test pressures stated in Section 10), provided the fiber stress corresponding to those test pressures does not exceed 24,000 psi. as determined by the above formula.

Test Specimens

11. (*a*) Test specimens required for the flattening and flaring tests under Sections 7 and 8 shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

(*b*) Tension tests, if desirable and practicable, may be made on full sections of the tubes up to the capacity of the testing machine. For larger size tubes, the tension specimen shall consist of a strip cut longitudinally from the tube and not flattened between gage marks. The sides of the specimen shall be parallel between gage marks; the width, irrespective of the thickness, shall be 1 in.; the gage length shall be 2 in.

(*c*) On tubes furnished with upset, swaged, or otherwise formed ends, the hardness test specified in Section 9 shall be made on the ends of the tubes after forming operation.

(*d*) All specimens shall be tested at room temperature.

Number of Tests

12. (*a*) From each group of 100 finished tubes, or fraction thereof, two tubes shall be selected at random for the tension test specified in Section 6.

(*b*) From each heat-treated lot of finished tubes, two tubes shall be selected at random for purpose of tests. The flattening test specified in Section 7 shall be made on each end of one of these tubes and the flaring test specified in Section 8 shall be made on each end of

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[6] 1936 Book of A.S.T.M. Standards, Part I, p. 824.

TABLE II.—STANDARD WEIGHTS OF CARBON-MOLYBDENUM ALLOY-STEEL BOILER AND SUPERHEATER TUBES.

NOTE.—The weights given in Table I are theoretical and are based on tubes having a perfect outside diameter, inside diameter, and wall thickness. Minimum wall tubes, as called for in these specifications, will weigh from 10 to 15 per cent heavier than those shown, depending on the size and wall thickness specified.

Wall Thickness in.	0.035	0.040	0.045	0.050	0.055	0.065	0.075	0.085	0.095	0.105	0.120	0.135	0.150	0.165	0.180	0.200
Wall Thickness, nearest B.w.g No.	20	19−	19+	18+	17−	16	15+	14+	13	12−	11	10+	9+	8	7	6−
Size, Outside Diameter, in.	Weight, lb. per ft. of length															
1/2	0.1738	0.1965	0.2187	0.2403	0.2614	0.3020	0.3404	0.3767	0.4109	0.4430	0.487	0.526	0.561	......	......	......
5/8	......	......	0.2787	0.3071	0.3348	0.3888	0.4406	0.4902	0.5377	0.5831	0.647	0.707	0.761	0.811	......	......
11/16	......	......	0.3090	0.3407	0.3718	0.4325	0.4910	0.5474	0.6017	0.6538	0.7279	0.797	0.862	0.922	0.977	......
3/4	......	......	0.3388	0.3738	0.4082	0.4755	0.5407	0.6037	0.6646	0.7233	0.8074	0.8867	0.961	1.031	1.096	1.175
13/16	......	......	......	0.4074	0.4452	0.5193	0.5911	0.6609	0.7285	0.7940	0.8881	0.9775	1.062	1.142	1.217	1.309
7/8	......	......	......	0.4406	0.4817	0.5623	0.6408	0.7172	0.7914	0.8635	0.9676	1.067	1.161	1.251	1.336	1.442
15/16	......	......	......	......	0.5187	0.6060	0.6913	0.7744	0.8553	0.9341	1.048	1.158	1.262	1.362	1.457	1.576
1	......	......	......	......	0.5551	0.6491	0.7409	0.8306	0.9182	1.004	1.128	1.247	1.362	1.471	1.576	1.709
1 1/8	......	......	......	......	0.6285	0.7359	0.8411	0.9441	1.045	1.144	1.288	1.427	1.562	1.692	1.817	1.976
1 3/16	......	......	......	......	......	0.7796	0.8915	1.001	1.109	1.214	1.369	1.518	1.663	1.803	1.938	2.110
1 1/4	......	......	......	......	......	0.8226	0.9412	1.058	1.172	1.284	1.448	1.608	1.762	1.912	2.057	2.243
1 3/8	......	......	......	......	......	0.9094	1.041	1.171	1.299	1.424	1.608	1.788	1.962	2.132	2.297	2.510
1 7/16	......	......	......	......	......	......	1.092	1.228	1.363	1.495	1.689	1.879	2.063	2.243	2.418	2.644
1 1/2	......	......	......	......	......	......	1.141	1.285	1.426	1.564	1.769	1.968	2.163	2.353	2.538	2.777
1 5/8	......	......	......	......	......	......	1.242	1.398	1.552	1.705	1.929	2.148	2.363	2.573	2.778	3.044
1 3/4	......	......	......	......	......	......	1.342	1.511	1.679	1.845	2.089	2.329	2.563	2.793	3.018	3.311
1 7/8	......	......	......	......	......	......	1.442	1.625	1.806	1.985	2.249	2.509	2.763	3.013	3.258	3.578
2	......	......	......	......	......	......	1.542	1.738	1.933	2.125	2.409	2.689	2.964	3.234	3.499	3.845
2 1/4	......	......	......	......	......	......	......	......	2.186	2.405	2.730	3.049	3.364	3.674	3.979	4.379
2 1/2	......	......	......	......	......	......	......	......	......	2.686	3.050	3.410	3.765	4.115	4.460	4.913
2 3/4	......	......	......	......	......	......	......	......	......	2.966	3.371	3.770	4.165	4.555	4.941	5.477
3	......	......	......	......	......	......	......	......	......	3.246	3.691	4.131	4.566	4.996	5.421	5.981
3 1/4	......	......	......	......	......	......	......	......	......	......	4.011	4.491	4.966	5.436	5.902	6.515
3 1/2	......	......	......	......	......	......	......	......	......	......	4.332	4.852	5.367	5.877	6.382	7.049
3 3/4	......	......	......	......	......	......	......	......	......	......	......	5.212	5.767	6.317	6.863	7.583
4	......	......	......	......	......	......	......	......	......	......	......	5.573	6.168	6.758	7.344	8.117
4 1/2	......	......	......	......	......	......	......	......	......	......	......	6.293	6.969	7.639	8.305	9.185
5	......	......	......	......	......	......	......	......	......	......	......	7.014	7.770	8.520	9.266	10.25

Wall Thickness, in.	0.220	0.240	0.260	0.280	0.300	0.320	0.340	0.360	0.380	0.400	0.420	0.440	0.460	0.480	0.500
Wall Thickness, nearest B.w.g. No.	5	4+	3+	2−	1	0	0	0	00	00	000	000	000	000	000
Size, Outside Diameter, in.	Weight, lb. per ft. of length														
13/16	1.393	......	......	......	......	......	......	......	......	......	......	......	......	......	......
7/8	1.539	1.628	......	......	......	......	......	......	......	......	......	......	......	......	......
15/16	1.687	1.789	1.883	......	......	......	......	......	......	......	......	......	......	......	......
1	1.833	1.948	2.055	2.153	......	......	......	......	......	......	......	......	......	......	......
1 1/8	2.126	2.268	2.402	2.527	2.643	......	......	......	......	......	......	......	......	......	......
1 3/16	2.274	2.427	2.574	2.712	2.845	2.963	......	......	......	......	......	......	......	......	......
1 1/4	2.420	2.589	2.749	2.901	3.044	3.178	3.304	......	......	......	......	......	......	......	......
1 3/8	2.714	2.909	3.096	3.274	3.444	3,606	3.758	3.902	......	......	......	......	......	......	......
1 7/16	2.862	3.071	3.271	3.463	3.646	3,821	3.987	4.145	4.294	......	......	......	......	......	......
1 1/2	3.007	3.230	3.443	3.648	3.845	4.033	4.212	4.383	4.545	4.699	......	......	......	......	......
1 5/8	3.301	3.550	3.790	4.022	4.245	4.460	4.666	4.864	5.053	5.233	5.405	......	......	......	......
1 3/4	3.595	3.870	4.137	4.396	4.646	4.887	5.120	5.344	5.560	5.767	5.966	6.156	......	......	......
1 7/8	3.889	4.191	4.485	4.770	5.046	5.314	5.574	5.825	6.067	6.301	6.527	6.743	6.952	7.151	......
2	4.182	4.511	4.831	5.143	5.447	5.742	6.028	6.305	6.575	6.835	7.087	7.331	7.566	7.792	8.010
2 1/4	4.770	5.152	5.525	5.891	6.248	6.596	6.936	7.267	7.589	7.903	8.209	8.506	8.794	9.074	9.345
2 1/2	5.357	5.792	6.220	6.638	7.049	7.450	7.843	8.228	8.604	8.971	9.330	9.680	10.02	10.36	10.68
2 3/4	5.944	6.433	6.914	7.386	7.850	8.305	8.751	9.189	9.618	10.04	10.46	10.86	11.25	11.64	12.02
3	6.532	7.074	7.608	8.133	8.651	9.159	9.659	10.15	10.63	11.11	11.57	12.03	12.48	12.92	13.35
3 1/4	7.119	7.715	8.302	8.881	9.452	10.013	10.57	11.11	11.65	12.18	12.69	13.21	13.71	14.20	14.69
3 1/2	7.707	8.356	8.996	9.629	10.25	10.868	11.48	12.07	12.66	13.24	13.82	14.38	14.94	15.48	16.02
3 3/4	8.294	8.996	9.691	10.38	11.05	11.722	12.38	13.03	13.68	14.31	14.94	15.55	16.16	16.76	17.36
4	8.881	9.637	10.39	11.12	11.85	12.577	13.29	14.00	14.69	15.38	16.06	16.73	17.39	18.05	18.69
4 1/2	10.06	10.92	11.77	12.62	13.46	14.286	15.11	15.92	16.72	17.52	18.30	19.08	19.85	20.61	21.36
5	11.23	12.20	13.16	14.11	15.06	15.994	16.92	17.84	18.75	19.65	20.54	21.43	22.30	23.17	24.03

the remaining tube. For the purpose of calculating the number of tests on tubes heat treated by the continuous process, the number of tubes in a heat-treated lot shall be determined from the size of the tubes as follows:

SIZE OF TUBE	SIZE OF LOT
2 in. and over in diameter and 0.200 in. and over in wall thickness	not more than 50 tubes
Less than 2 in. but over 1 in. in diameter or over 1 in. in diameter and under 0.200 in. in wall thickness	not more than 75 tubes
1 in. or less in diameter	not more than 125 tubes

TABLE III.—PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHTS.

Size, Outside Diameter, in.	Outside Diameter (including out of roundness), in.[a,b]		Wall Thickness, per cent[a, c]								Weight[d] per foot, per cent		Length Cut, in.[e]	
			0.095 in. and under		Over 0.095 to 0.150 in., incl.		Over 0.150 to 0.180 in., incl.		Over 0.180 in.					
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
HOT-FINISHED TUBES														
4 and under	1/64	1/32	40	0	35	0	33	0	28	0	16	0	3/16	0
Over 4	1/64	3/64	..	..	35	0	33	0	28	0	16	0	3/16	0
COLD-DRAWN TUBES														
			Over				Under							
Under 1	0.004	0.004	20				0				12	0	1/8	0
1 to 1½, incl.	0.006	0.006	20				0				12	0	1/8	0
Over 1½ to under 2	0.008	0.008	22				0				13	0	1/8	0
2 to under 2½	0.010	0.010	22				0				13	0	3/16	0
2½ to under 3	0.012	0.012	22				0				13	0	3/16	0
3 to 4, incl	0.015	0.015	22				0				13	0	3/16	0
Over 4	0.015	0.025	22				0				13	0	3/16	0

[a] The gaging tolerances given apply only to the tubes as rolled or drawn and before swaging, expanding, bending polishing, or other fabricating operations.

[b] Cold-drawn tubing having a specified wall thickness which is 3 per cent, or less than 3 per cent, of the outside diameter cannot be straightened properly without a certain amount of ovality resulting in the diameter, consequently such tubes, while having an average outside diameter within the permissible variations shown in the table, will require an additional ovality permissible variation of plus or minus 0.5 per cent of the outside diameter.

[c] On tubes 2 in. and over in outside diameter and 0.220 in. in thickness and over the variation in wall thickness in any one cross-section of any one tube shall not exceed plus or minus 10 per cent of the actual average wall of that section. The actual average wall is defined as the average of the thickest and thinnest wall in that section.

[d] The permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. in outside diameter and under, and to lots of 20 tubes or more in sizes over 4 in. in outside diameter.

[e] Permissible variations in length apply to tubes before bending.

(*c*) Five per cent of all tubes shall be selected for the hardness tests, specified in Section 9 and one Brinell or one or more Rockwell tests shall be made on each of these tubes.

(*d*) Each tube shall be subjected to the hydrostatic test, specified in Section 10.

Retest

13. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 6, 7, 8 and 9, retests may be made on additional tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

(*b*) If any tension test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted. If the elongation of any tension test specimen is less than that specified, and any part of the fracture is more than ¾ in. from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retreatment

14. If individual tubes or tubes selected to represent any group or lot fail to meet the test requirements specified in Sections 6, 7, 8 and 9, the individual

tubes or group or lot represented may be retreated and resubmitted for test. Only two reheat treatments will be permitted.

Forming Operations

15. Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

Standard Weights

16. The standard weights for tubes of various outside diameters and wall thicknesses are given in Table II.

Permissible Variations in Dimensions and Weight

17. Variations in outside diameter, wall thickness, weight, and length, from those specified, shall not exceed the amount shown in Table III.

Finish

18. Finished tubes shall be reasonably straight and have smooth ends, free from burrs. They shall be free from injurious defects and have a workmanlike finish. Minor defects may be removed by grinding provided the wall thicknesses are not decreased to less than that permitted in Section 17.

Marking

19. (*a*) The name or brand of the manufacturer, the grade of the material from which it is made (such as, T1 or T1a), A.S.T.M. Specification A 209 – 38 T, together with the hydrostatic test pressure in pounds per square inch, and whether hot finished or cold drawn, shall be legibly stenciled on each tube $1\frac{1}{4}$ in. in outside diameter and over, provided the length is not under 3 ft.

(*b*) On tubes less than $1\frac{1}{4}$ in. in diameter and on all tubes under 3 ft. in length, the information prescribed in Paragraph (*a*) shall be indicated on a tag securely attached to the bundle or box in which the tubes are shipped.

Inspection

20. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture.

Certification

(*b*) When required, the manufacturer shall furnish the purchaser of each lot of tubes a statement as to the kind of material of which the tubes are made and certifying that the tubes have been tested and have met all the requirements of these specifications.

Pickling or Shot Blasting

(*c*) If pickling or shot blasting, or both are required, this shall be specifically stated in the order and shall be done at the purchaser's expense.

Rejection

21. (*a*) When inspection at the place of manufacture has been waived, any rejection based on tests made in accordance with Section 5 (*a*) shall be reported, by the purchaser, within five working days from receipt of samples.

(*b*) Tubes which fail in any of the forming operations provided for under Section 15 will be rejected and the manufacturer shall be notified.

Rehearing

22. Samples tested in accordance with Section 5 (*a*) or 5 (*b*) which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Tentative Specifications for
SPIRAL WELDED STEEL OR IRON PIPE[1]

A.S.T.M. Designation: A 211 – 38 T

ISSUED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover spiral-welded steel or iron pipe 4 to 48 in., inclusive, in diameter, and $\frac{1}{16}$ to $\frac{11}{64}$ in. (No. 16 to No. 8 U. S. standard gage), inclusive, in wall thickness. This pipe is intended for conveying liquid, gas, or vapor. The suitability of pipe for various purposes is somewhat dependent upon its dimensions, properties, and conditions of service, so that the purpose for which the pipe is intended should be stated in the purchase order.

Material

2. The steel or iron coils, or sheets shall conform to the chemical and physical requirements of one of the following specifications of the American Society for Testing Materials,[3] or to other A.S.T.M. specifications for equally suitable weldable material, as specified:

Standard Specifications for Steel Plates of Structural Quality for Forge Welding (A.S.T.M. Designation: A 78),[4]

Standard Specifications for Steel Plates of Flange and Firebox Qualities for Forge Welding (A.S.T.M. Designation: A 89),[5] and

Standard Specifications for Open-Hearth Iron Plates of Flange Quality (A.S.T.M. Designation: A 129).[6]

Manufacture

3. (*a*) The pipe shall be made by one of the following electric-fusion-welded processes: spiral-lap-joint, spiral-lock-seam-joint, or spiral-butt-welded-joint.

(*b*) The coils or sheets used in the manufacture of the pipe shall be trimmed to the proper width and given any special edge treatment required by the welding process. The material shall then be rolled so that a helical seam is formed around the circumference of the pipe. The electric-arc-welding operation performed to fuse or seal the edges or surfaces of the helical seam shall produce a uniform weld for the entire length of the seam.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

[3] It is the opinion of Committee A-1 on Steel that steel or iron made in accordance with the following specifications of the American Society for Testing Materials can be welded satisfactorily by the usual fusion-welding processes now in general use:

Standard Specifications for Steel Plates of Structural Quality for Forge Welding (A 78), Steel Plates of Flange and Firebox Qualities for Forge Welding (A 89), Steel for Bridges (A 7), Steel for Buildings (A 9), Mild Steel Plates (A 10), Structural Steel for Locomotives and Cars (A 113), Boiler and Firebox Steel for Locomotives (A 30), Marine Boiler Steel Plates (A 114), Open Hearth Iron Plates of Flange Quality (A 129), Uncoated Wrought Iron Sheets (A 162), Structural Steel for Ships (A 131), and Carbon Steel Plates for Stationary Boilers and Other Pressure Vessels (A 70).

In connection with carbon limitations in the above specifications, the committee was of the opinion that, while higher carbon steels are being successfully welded, commercial practice at present often limits the carbon (by check analysis) to 0.35 per cent in open-hearth steel.

[4] 1936 Book of A.S.T.M. Standards, Part I, p. 88.

[5] *Ibid.*, p. 82.

[6] *Ibid.*, p. 78.

Hydrostatic Test

4. Unless otherwise specified, each length of pipe shall be tested at the mill to a hydrostatic pressure equal to a minimum of 150 per cent of the working pressure, but in no case shall the maximum stress produced exceed 80 per cent of the yield point of the material specified. The working pressure shall be calculated from the following formula:

$$P = \frac{2St}{D}$$

where:

P = the working pressure in pounds per square inch,

S = the allowable fiber stress in pounds per square inch,

t = the wall thickness in inches, and

D = the outside diameter in inches.

Weights, Dimensions, and Permissible Variations

5. (*a*) *Weight.*—Permissible variations on the theoretical weights of pipe shall be governed by the permissible variations in weight for plates as covered by the specifications of the American Society for Testing Materials to which the plates are ordered, or to the permissible variations in weight made a part of other specifications as may cover suitable weldable materials in accordance with Section 2. Actual weights and thicknesses may be determined while the stock is flat and before it is formed into pipe.

(*b*) *Diameter.*—The outside diameter of the pipe shall be within the permissible variations consistent with the requirements of field joints as agreed upon by the manufacturer and the purchaser.

(*c*) *Length.*—Pipe shall be furnished in standard lengths of 20 ft., 30 ft., or 40 ft. as specified in the purchase order except that closure pieces and specials, such as reducers, elbows, etc., shall be furnished in lengths appropriate to the installation requirements.

Workmanship and Finish

6. (*a*) Finished pipe shall be reasonably straight, free from injurious defects, and with the ends prepared as specified in the purchase order.

(*b*) Injurious defects in the pipe wall, the depth of which do not exceed one-third the specified wall thickness, shall be repaired by welding. Defects in the welds, such as sweats or leaks, unless otherwise specified, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then welding. All repaired pipe shall be retested hydrostatically.

Protective Coating

7. After the pipe has been subjected to the hydrostatic test, and if required by the purchaser, it shall be thoroughly cleaned of all dirt, oil, grease, loose scale, and rust, then dried, and given a protective coating of the kind and in the manner specified by the purchaser.

Inspection

8. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these

specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

9. Each length of pipe which develops injurious defects during shop working or application operations will be rejected, and the manufacturer shall be notified.

TENTATIVE SPECIFICATIONS

FOR

CARBON AND ALLOY-STEEL NUTS FOR BOLTS FOR HIGH-PRESSURE AND HIGH-TEMPERATURE SERVICE TO 1100 F.[1]

A.S.T.M. Designation: A 194 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1936; REVISED, 1938.[2]

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. (*a*) These specifications cover steel nuts for bolts used in high-pressure or high-temperature service, or both, up to 1100 F.

(*b*) Five classes of material for services varying in degree of severity are covered: Class 0 for service under the least exacting conditions, Classes 3 and 4 for service under the most severe conditions, and Classes 1, 2 and 2H for service conditions between these extremes.

Certification of Test

2. Where mutually agreed upon in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements specified may be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the results of the physical tests made in accordance with these specifications and, when required in the purchase order, the chemical analysis also. In all cases, whether a certification of test or the results of the physical tests are furnished, there shall be furnished when required in the purchase order a report giving the minimum drawing temperature for nuts of Classes 2H, 3 and 4.

Process

3. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, or acid-bessemer.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Latest revision accepted by Committee E-10 on Standards, August 25, 1938.

Fabrication

4. (*a*) Class 0 nuts shall be made by the hot-forged process, cold process, or machined from bar stock.

(*b*) Classes 1 and 2 nuts shall be made by the hot-forged or cold processes, or machined from hot-forged or hot-rolled bars.

(*c*) Classes 2H, 3 and 4 nuts shall be made by the hot-forged or cold processes, or machined from hot-forged or hot-rolled bars and shall be heat treated to meet the required physical properties. These classes of nuts shall be quenched and drawn at a temperature at least 100 F. above the service temperature, but in no case less than 850 F. for Classes 2H and 3 and not less than 1100 F. for Class 4 nuts.

Stress Relieving

5. (*a*) Before tapping, all nuts, excepting Class 0, made by the cold process shall be heated in the process of manufacturing to a temperature of at least 1000 F. (538 C.).

(*b*) Nuts made by the hot process or from hot-forged or hot-rolled bars need not be subjected to this stress relieving.

Chemical Composition

6. Classes 0, 1, 2, 2H, 3 and 4 analyses will be furnished the purchaser only when specified in the order, and shall conform to the following requirements as to chemical composition for the respective classes:

	CLASS 0	CLASS 1	CLASSES 2 AND 2H	CLASS 3[a]	CLASS 4
Carbon, per cent	0.25 max.	0.15 min.	0.40 min.	0.20 min.	0.40 to 0.50
Chromium, per cent	....	....	....	4.0 to 6.0	....
Manganese, per cent	....	....	....	....	0.50 to 0.95
Molybdenum, per cent	....	....	....	0.45 to 0.65[b]	0.20 min.
Silicon, per cent	....	....	....	0.50 max.	0.15 min.
Tungsten, per cent	....	....	....	0.75 to 1.25[b]	....
Phosphorus, max., per cent	0.10	0.05	0.05	0.05	0.04
Sulfur, max., per cent	0.15	0.05	0.05	0.05	0.05

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[a] Other types of alloy steel, with their appropriate heat treatments, approved by the purchaser may be submitted under these specifications.

[b] Either molybdenum or tungsten may be used, if desired.

Ladle Analysis

7. (*a*) A carbon determination of each melt of bessemer steel shall be made, and determinations for manganese, phosphorus and sulfur representing the average of the melts applied for each 8-hr. period.

(*b*) An analysis of each melt of open-hearth or electric-furnace steel shall be made to determine the percentage of carbon, manganese, phosphorus, sulfur or each alloy used.

(*c*) The analysis prescribed in Paragraph (*b*) shall be made by the manufacturer from test ingots taken during the pouring of each melt. When specified on the purchase order, the results of this analysis shall be reported to the purchaser or his representative and the chemical composition thus determined shall conform to the requirements specified in Section 6.

Check Analysis

8. An analysis may be made by the purchaser from a finished nut representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 6 by more than 25 per cent, and the other elements shall conform to the specified requirements.

Brinell Hardness Test

9. (*a*) Class 0 nuts in the condition as manufactured shall show a minimum Brinell hardness of 120.

(*b*) Samples of each class of nuts, except Class 0 shall show the Brinell hardness specified below: (*1*) in the finished condition; (*2*) after the sample has been subjected for 24 hr. to a temperature of 850 F. (455 C.) for Class 1, 1000 F. (540 C.) for Classes 2 and 2H, and 1100 F. (590 C.) for Classes 3 and 4, and then cooled slowly:

	Brinell Hardness	
Class	Sample Nut as Finished	Sample Nut After Treatment as in Paragraph (*b*)
1	120 min.	120 min.
2	160 min.	160 min.
2H	248 to 352	180 min.
3	248 to 352	200 min.
4	248 to 352	200 min.

(*c*) Brinell hardness tests shall be made on the side of the nut in accordance with the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Drift Test

10. Classes 2H, 3, and 4 nuts when machined from bar stock, and all other classes of nuts shall be capable of meeting the following drift test: A conical mandrel, part of which has a diameter equal to the nominal nut size, shall be forced through the tapped hole to the nominal nut size, cold, without cracking the body of the nut. The test may be continued until the nut is broken for examination of the structure.

Stripping Test

11. Nuts of Classes 1, 2, 2H, 3, and 4 shall be capable of meeting the following stripping test: A nut shall be assembled on a piece of bolting material held in a tension testing machine so that a load is applied to the nut. The threads in the nut shall not strip when subjected to a stress equal to 150,000 lb. per sq. in. figured from the mean diameter[2] of the bolt.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 817.

[2] Mean diameter is the average of the root and pitch diameters.

Number of Tests

12. When so specified on the purchase order, the purchaser's representative may select two nuts per keg for sizes ⅝ in. and smaller, one nut per keg for sizes over ⅝ in. up to and including 1½ in., and one nut per every two kegs for sizes larger than 1½ in., and they shall be subjected to the tests specified in Sections 9, 10, and 11. Periodic control tests when made by the manufacturer on each lot of nuts may be considered sufficient for certification purposes in accordance with Section 2.

Retest

13. If the results of any physical test do not conform to the requirements specified, two additional tests from the same lot shall be made, each of which shall conform to the requirements specified.

Finish

14. Nuts shall be free from injurious defects and shall have a workmanlike finish.

15. (*a*) Nuts shall be semifinished, hexagonal in shape and in accordance with the dimensions for the Regular or Heavy Series, as required, of the American Standard for Wrench-Head Bolts and Nuts and Wrench Openings (A.S.A. No.: B18.2–1933). Unless otherwise specified, the American Standard Heavy Series shall be used.

(*b*) The threads in nuts shall be in accordance with the American Standard for Screw Threads (A.S.A. No.: B1.1–1935).

(*c*) Nuts for use with American Standards for pipe flanges and flanged fittings shall have dimensions in accordance with the Heavy Series of the American Standard for Wrench-Head Bolts and Nuts and Wrench Openings (A.S.A. No.: B18.2–1933). Threads in accordance with the American Standard coarse-thread series shall be used except that nuts of sizes 1⅛ in. and larger for use with the American Standard for Steel Flanged Fittings and Companion Flanges (A.S.A. No.: B16e–1932) shall be threaded in accordance with the American Standard 8-Pitch-Thread Series.

Marking

16. (*a*) All nuts shall bear the manufacturer's identification mark.

(*b*) Nuts shall be legibly stamped to indicate the class and the process of manufacture, as follows:

	MARKING	
CLASS	NUTS HOT FORGED OR COLD PUNCHED	NUTS MACHINED FROM BAR STOCK
0	no marking	0
1	1	1B
2	2	2B
2H	2H[a]	2HB[a]
3	3	3B
4	4	4B

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[a] The letter H indicates heat-treated nuts (see Sections 4 (c) and 6).

Inspection

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the nuts ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the nuts are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made in the presence of the purchaser's representative and shall be made prior to shipment.

(*b*) The purchaser may make, at his own expense, in his own laboratory or elsewhere, additional tests in accordance with these specifications to govern the acceptance or rejection of the nuts.

Rejection

18. Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer within twelve working days from the receipt of samples.

Rehearing

19. Nuts that have been rejected shall be preserved for two weeks from the date the test report is submitted to the manufacturer. In case of dissatisfaction with the results of test, the manufacturer may make claim for a rehearing within that time.

A.S.M.E. BOILER CONSTRUCTION CODE
SPECIFICATION No.: S-34

TENTATIVE SPECIFICATIONS

FOR

SEAMLESS ALLOY-STEEL PIPE FOR SERVICE AT TEMPERATURES FROM 750 TO 1100 F.[1]

A.S.T.M. Designation: A 158 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1934; Adopted in Amended Form, 1936; Reissued as Tentative, 1937; Revised, 1938.

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Scope

1. (*a*) These specifications are intended as a general guide for the purchase of alloy-steel pipe and to serve as a basis for agreement between the purchaser and the manufacturer as to details not specifically covered.

(*b*) These specifications cover seamless alloy-steel pipe intended for service at metal temperatures from 750 to 1100 F.; both ferritic and austenitic steels, designated P 3a, P 6, etc., are included (see Explanatory Note 1). The maximum temperature at which the pipe will be operated in service shall be stated in the purchase order. Choice from the respective steels should be made on the basis of the requirements of design, service conditions, and the physical properties (see Explanatory Note 2).

(*c*) Supplementary requirements (Paragraphs S1 to S6) of an optional nature are provided for pipe intended for use in central stations having steam service pressures of 400 lb. per sq. in. or over and temperatures up to 1100 F., or other applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made at the expense of the purchaser, and when desired shall be so stated in the order.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Certification

2. Where mutually agreed upon in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements of these specifications shall be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the results of the chemical analyses and physical tests made in accordance with these specifications.

Process

3. (*a*) The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

(*b*) Unless otherwise specified, all pipe 2 in. and over in nominal diameter shall be furnished hot-finished followed by the treatment specified in Section 5.

(*c*) Unless otherwise specified, pipe under 2 in. in nominal diameter may be furnished either hot-finished or cold-drawn, with, where necessary, a suitable manufacturer's finishing treatment.

Discard

4. Sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Heat Treatment

5. (*a*) All ferritic steels covered in Section 3 other than Grade P 5c shall be reheated and furnished in a full-annealed or normalized and drawn condition as stated in the purchase order. If furnished in the normalized and drawn condition, the temperature for drawing shall be at least 200 F. above the service temperature as given in the purchase order (Note 1).

(*b*) Grade P 5c steel, unless otherwise specified, shall be treated by heating to approximately 1350 F. for a proper time, followed by air or furnace cooling.

(*c*) All austenitic steels shall be heat treated (Note 2) according to present accepted practice.

NOTE 1.—Certain of the ferritic steels covered by these specifications will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly the 4 to 6 per cent chromium steels, P 5. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging and hot bending, should be followed by suitable heat treatment.

NOTE 2.—Fabricating operations involving upsetting, flanging, bending, and forming often make retreating desirable to insure adequate corrosion resistance depending upon service conditions.

Chemical Composition[1]

6. Each alloy[2] shall conform to the following requirements as to chemical composition,[3] or to other chemical composition requirements as specified in the purchase order:

Class	Ferritic Steels					
Identification Symbol	P 3a	P 3b	P 5a	P 5b	P 5c	P 6
Grade	Chromium-Molybdenum	Chromium-Molybdenum	4 to 6 per cent Chromium	4 to 6 per cent Chromium-Silicon-Molybdenum	4 to 6 per cent Chromium-Molybdenum Stabilized with Titanium or Columbium	13 per cent Chromium
Carbon, per cent	0.15 max.	0.15 max.	0.15 max. or 0.20 max.	0.15 max.	As specified 0.10 or 0.15 max.	0.12 max.
Manganese, per cent	0.40 to 0.60	0.30 to 0.60	0.50 max.	0.30 max.	0.50 max.	0.50 max.
Phosphorus, max., per cent	0.04	0.03	0.03	0.03	0.03	0.03
Sulfur, max., per cent	0.05	0.03	0.03	0.03	0.03	0.03
Silicon, per cent	0.45 to 0.75	0.50 max.	0.50 max.	1.00 to 2.00	0.50 max.	0.50 max.
Nickel, per cent	....	....	....	....	....	....
Chromium, per cent	1.50 to 2.00	1.75 to 2.25	4.00 to 6.00	4.00 to 6.00	4.00 to 6.00	12.00 to 15.00
Molybdenum, per cent	0.60 to 0.80	0.45 to 0.65	0.45 to 0.65[a]	0.45 to 0.65	0.45 to 0.65	....
Tungsten, per cent	....	....	0.75 to 1.25[a]	....	....	2.50 to 3.50
Titanium	....	....	....	....	4 to 6 times carbon	....
or Columbium	....	....	....	....	8 to 10 times carbon	....

Class	Ferritic Steels		Austenitic Steels		
Identification Symbol	P 11	P 15	P 8a	P 8b	P 8c[b]
Grade	Chromium-Molybdenum	Silicon-Molybdenum	18 Chromium-8 Nickel	18 Chromium 10 Nickel Stabilized with Titanium or Columbium	18 Chromium 8 Nickel 2 Silicon
Carbon, max., per cent	0.15	0.15	0.07	0.08	0.25
Manganese, per cent	0.30 to 0.60	0.30 max.	0.20 to 0.70	0.70 max.	0.50 to 0.70
Phosphorus, per cent	0.04	0.04	0.03	0.03	0.03
Sulfur, per cent	0.05	0.045	0.03	0.03	0.03
Silicon, per cent	0.50 to 1.00	1.15 to 1.65	0.75 max.	0.50 max.	1.00 to 3.00
Nickel, per cent	....	....	8.00 to 10.00	9.00 to 12.00	8.00 to 10.00
Chromium, per cent	1.00 to 1.50	....	17.00 to 20.00	17.00 to 19.00	17.00 to 19.00
Molybdenum, per cent	0.45 to 0.65	0.45 to 0.65	....	....	....
Tungsten, per cent	....	....	....	....	....
Titanium	....	....	....	0.35 min.	....
or Columbium	....	....	....	8 times carbon content, min.	....

[a] Either molybdenum or tungsten shall be used.

[b] Grade P8c was formerly designated P13.

Ladle Analysis

7. A ladle analysis of each melt of steel shall be made by the steel manufacturer. The chemical composition thus determined, or that

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

[2] Alloys have been numbered so that similar alloys in the corresponding specifications for forgings, castings, and bolting will bear the same number for alloys numbered 10 or below. No alloys P 4, P 7 or P 10 are included herein as the particular compositions corresponding to these numbers are not included in these specifications.

[3] The list is incomplete and will be reviewed annually and revised promptly when necessary.

determined from a check analysis made by the pipe manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 6.

Check Analysis

8. (*a*) At the request of the purchaser's inspector, analyses as specified below shall be made by the manufacturer from the finished pipe and shall conform to the requirements specified in Section 6:

NOMINAL DIAMETER	NUMBER OF PIPES SELECTED
Under 2 in.	2 pipes from each lot of 400 lengths or fraction thereof
2 to 5 in. inclusive	2 pipes from each lot of 200 lengths or fraction thereof
6 in. and over	2 pipes from each lot of 100 lengths or fraction thereof

Results of these analyses shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 6.

(*b*) Drillings for analysis from pipe shall be taken from several points around each pipe selected for analysis. Drillings for analysis from billets shall be taken at a point midway between the outside and center of the billet by drilling parallel to the axis.

(*c*) If the analysis of one of the tests specified in Section 7 or 8 (*a*) does not conform to the requirements specified in Section 6, analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

Tension Tests

9. (*a*) The material shall conform to the following minimum requirements as to tensile properties[1] at room temperature:

	FERRITIC STEELS	AUSTENITIC STEELS
Tensile strength, min., lb. per sq. in.	60 000[a]	75 000[a]
Yield point, min., lb. per sq. in.:		
Fully annealed	25 000[a]	......
Normalized and drawn	30 000[a]	......
Rapidly air-cooled or quenched	......	30 000[a]
Elongation in 2 in., min., per cent	30[a]	50[a]

[a] For transverse tension tests the material shall conform to these minimum tensile requirements except that the elongation in 2 in. shall be 25 per cent for the ferritic steels and 40 per cent for the austenitic steels.

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by the use of dividers or other approved method, at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. Where a definite yield point is not exhibited, the yield strength, corresponding to a limiting permanent set of 0.2 per cent of the gage length of the specimen, shall be reported instead. The "offset method" of determining yield strength as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[1] shall be followed. The tensile strength shall be determined at a crosshead speed not to exceed $1\frac{1}{2}$ in. per minute.

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

Hydrostatic Tests

10. (*a*) Unless otherwise mutually agreed upon between the manufacturer and the purchaser, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress of 50 per cent of the minimum specified yield point at room temperature. This pressure shall be determined by the formula:

$$P = \frac{2St}{D}$$

where P = the minimum hydrostatic test pressure in pounds per square inch,

S = 0.50 times the minimum specified yield point at room temperature in pounds per square inch,

t = the nominal wall thickness in inches, and

D = the outside diameter in inches.

(*b*) The maximum hydrostatic test pressure shall not exceed 2500 lb. per sq. in. for sizes 3 in. or under in outside diameter, nor 4500 lb. per sq. in. for sizes over 3 in. to but not including $8\frac{5}{8}$ in. in outside diameter, and 3000 lb. per sq. in. for all sizes $8\frac{5}{8}$ in. or over in outside diameter. The hydrostatic pressure shall be maintained for not less than 5 sec.

Flattening Tests

11. For pipe over 2 in. in nominal diameter, a section of pipe not less than $2\frac{1}{2}$ in. in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. No cracks or breaks in the metal shall occur until the distance between the plates is less than one half the outside diameter of the pipe, but in no case less than seven times the thickness of the pipe wall. Evidence of laminations or burnt material shall not develop during the entire flattening process.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

Bend Tests

12. For pipe 2 in. or under in nominal diameter, a sufficient length of pipe shall stand being bent cold through 90 deg. around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180 deg. around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

Test Specimens

13. (*a*) Specimens cut either longitudinally or transversely shall be acceptable for tension tests.

(*b*) Longitudinal tension tests may be made in full section of the pipe up to the capacity of the testing machine. For larger sizes, the tension test specimens shall consist of strips cut from the pipe. The width of these specimens shall be 1½ in. and shall have a gage length of 2 in. When the pipe wall thickness exceeds ¾ in., the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Longitudinal tension specimens shall not be flattened between gage marks. The sides of specimens shall be parallel between gage marks.

(*c*) The transverse tension test may be made on pipe 8 in. and over in nominal diameter. Specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. The specimen shall consist of a strip cut transversely from the pipe; the width of the specimen shall be 1½ in. and its gage length 2 in. When the pipe wall thickness exceeds ¾ in., the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Specimens shall be flattened hot and heat treated in the same manner as the pipe, and shall be parallel between gage marks. At the option of the manufacturer, the transverse tension test specimen may be machined off on either surface provided not over 15 per cent of the nominal thickness is removed from either side.

NOTE.—The standard tension test specimens are described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

(*d*) Test specimens for flattening and bend tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

(*e*) All routine check tests shall be made at room temperature

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

Number of Tests

14. (*a*) Tests shall be made as follows on one pipe from each heat-treated lot, but in no case on less than 5 per cent of the pipe ordered. Results of these tests shall be reported to the purchaser or his representative:

One transverse or longitudinal tension test specified in Section 9.

The flattening test specified in Section 11 for pipe over 2 in. in nominal diameter.

The bend test specified in Section 12 for pipe 2 in. or under in nominal diameter.

(*b*) For material heat treated by the continuous process, the tests specified in Paragraph (*a*) shall be made on each pipe in a lot constituting 5 per cent of the pipe ordered, but on not less than two pipes.

(*c*) Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

Retests

15. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 9, 11, or 12, retests shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

(*b*) If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than ¾ in. from the center of the gage length of the specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

(*c*) If any specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Retreatment

16. If individual lengths of pipe selected to represent any lot fail to meet the test requirements specified in Sections 9, 11, or 12, the lot may be heat treated again and resubmitted for test, except that any individual lengths which meet the test requirements before retreating will be acceptable.

Permissible Variations in Weight and Dimensions

17. (*a*) *Weight.*—The weight of any length of pipe in sizes up to and including 12 in. shall not vary more than 3.5 per cent under and 6.5 per cent over that specified. For sizes over 12 in. the weight of any length shall not vary more than 5 per cent under and 10 per

cent over that specified. Unless otherwise mutually agreed upon between the manufacturer and the purchaser, pipe in sizes smaller than 4 in. may be weighed in convenient lots; pipe in sizes 4 in. and larger shall be weighed separately.

(*b*) *Diameter.*—Variations in outside diameter shall not exceed those shown in the following table:

NOMINAL DIAMETER	PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETERS UNDER	 OVER
⅛ to 1½ in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{64}$ in. (0.015 in.)
2 to 4 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{32}$ in. (0.031 in.)
5 to 8 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{16}$ in. (0.062 in.)
10 to 18 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{3}{32}$ in. (0.093 in.)
20 to 24 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	⅛ in. (0.125 in.)

(*c*) *Thickness.*—The minimum wall thickness at any point shall not be more than 12.5 per cent under the nominal wall thickness specified.

(*d*) *Length.*—Pipe lengths shall be in accordance with the following regular practice:

> The lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. over that specified.
>
> No jointers are permitted unless otherwise specified.

Ends

18. Unless otherwise specified, pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

Finish

19. (*a*) The finished pipe shall be reasonably straight and free from injurious defects, and shall have a workmanlike finish.

Depth of Injurious Defects

(*b*) When the depth of defect in the pipe encroaches on the minimum wall thickness (87.5 per cent of the nominal thickness), or is in excess of 12.5 per cent of the nominal wall thickness, such defects shall be considered injurious.

Machining or Grinding Defects

(*c*) Pipe showing moderate slivers may be machined or ground inside or outside to a depth which shall insure the removal of all included scale and slivers, providing the wall thickness is not reduced below the minimum wall thickness required in these specifications. Machining or grinding shall follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

Repair by Welding

(*d*) Repair of injurious defects shall be permitted only subject to the approval of the purchaser and with the further understanding that the composition of the welding rod shall be suitable for the composition of the metal being welded. Welding of injurious defects in no case shall be permitted when the depth of defect exceeds 33⅓ per cent of the nominal pipe wall thickness or the length of repair exceeds 25 per cent of the nominal diameter of the pipe. Defects shall be thoroughly chipped out before welding, and then heat treated in accordance with Section 5. Each length of repaired pipe shall be retested hydrostatically in accordance with Section 10.

Marking

20. Each length of pipe manufactured in accordance with these specifications shall be legibly marked, either by stenciling, stamping, or rolling, with the manufacturer's private identifying mark, together with the symbols A 158 and the alloy symbol (as A 158 – P6) and **an additional S if pipe meets the supplementary requirements specified in Paragraphs S1 to S7.** Marking shall be within 12 in. of one end of each length. On pipe sizes 4 in. and larger, the weight shall be given. On small diameter pipe which is bundled, the above information may be legibly stamped on a metal tag securely attached to each bundle. When pipe marked as specified in this section is rejected, the designation A 158 shall be canceled.

Inspection

21. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment and at the manufacturer's expense, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

22. Each length of pipe which develops injurious defects in shop working or application shall be rejected, and the manufacturer shall be notified. No rejections under these or any other specifications, shall be marked as specified in Section 20 for sale under these specifications except where such pipe fails to comply with the weight requirements alone, in which case it may be sold under the weight specifications with which it does comply.

SUPPLEMENTARY REQUIREMENTS FOR SEAMLESS PIPE FOR USE IN CENTRAL STATIONS AT PRESSURES OF 400 LB. PER SQ. IN., OR OVER, AND TEMPERATURES OF 750 F. TO 1100 F., OR OTHER APPLICATIONS WHERE A SUPERIOR GRADE OF PIPE IS REQUIRED

S1. These requirements shall not be considered unless specified in the order, in which event the supplementary tests shall be made at the mill, unless otherwise agreed upon, at the purchaser's expense and witnessed by his inspector before shipment of the material.

Check Analysis

S2. Check analysis may be made on any length of pipe. Individual lengths failing to meet the chemical requirements specified in Section 6 shall be rejected.

Transverse Tension Tests

S3. Transverse tension tests may be made on specimens from both ends of each length of pipe. If the specimen from either end of any length fails to meet the physical properties specified in Section 9, that length shall be rejected.

Flattening Tests

S4. The flattening tests specified in Section 11 may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to meet the specified requirements, that length shall be rejected.

Finish and Metal Structure

S5. The finished pipe shall be free from all immoderate slivers and depressions. The steel shall have a homogeneous structure as shown by the etching test in Paragraph S6.

Etching Tests

S6. Etching tests[1] may be made on sections from any pipe, and shall show sound and reasonably uniform material, free from injurious laminations, cracks and similar objectionable defects. Sections used for the flattening tests described in Section 11 may be used for the etching test. If the specimen from any length shows objectionable defects, that length may be rejected.

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[1] Pending development of etching methods applicable to the product covered by these specifications, it is recommended the Tentative Recommended Practice for a Macro-Etch Test for Steel described in the *National Metals Handbook*, Am. Soc. for Metals, 1936 edition, p. 573, be followed.

Rejection

S7. At the purchaser's discretion, if 10 per cent of the pipe in any one lot fail to conform to the requirements of Paragraphs S2 to S6, the entire lot may be rejected. Rejection of a lot shall be based on tests from not less than two pipes. A lot shall consist of all the pipe bought by a purchaser of the same size and wall thickness from any one heat.

EXPLANATORY NOTES

NOTE 1.—The subcommittee formulating these specifications has included several classes of material that have been rather extensively used. Upon mutual agreement between the manufacturer and the purchaser, other classes of material may be employed, provided they otherwise meet the requirements of these specifications. Other compositions will be considered for inclusion in these specifications by the committee from time to time as the need becomes apparent.

NOTE 2.—Pending the incorporation of high-temperature data in an appendix, which it is the purpose in due time to add, high-temperature properties, when it is desired that the same be indicated or specified, shall be a matter of agreement between the manufacturer and the purchaser. No high-temperature tests shall be required on the materials selected unless a matter of agreement between the manufacturer and the purchaser. When required, the short-time tests at elevated temperature shall be in accordance with the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 21 - 37 T)[1] and the creep tests shall be in accordance with the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 22 - 38 T)[2] of the American Society for Testing Materials.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1290 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1654.

[2] See p. 1301.

TENTATIVE SPECIFICATIONS

FOR

SEAMLESS CARBON-MOLYBDENUM ALLOY-STEEL PIPE FOR SERVICE AT TEMPERATURES FROM 750 TO 1000 F.[1]

A.S.T.M. Designation: A 206 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. (*a*) These specifications cover seamless carbon-molybdenum alloy-steel pipe intended for service at metal temperatures from 750 to 1000 F. The maximum temperature at which the pipe will be operated in service shall be stated in the purchase order (see Explanatory Note). Pipe ordered under these specifications shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding.

(*b*) Supplementary requirements (Paragraphs S1 to S6) of an optional nature are provided for pipe intended for use in central stations having steam service pressures of 400 lb. per sq. in. or over and temperatures up to 1000 F., or other applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made at the expense of the purchaser, and when desired shall be so stated in the order.

Certification

2. Where mutually agreed upon in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements of these specifications shall be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the results of the chemical analyses and physical tests made in accordance with these specifications.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Process

3. (*a*) The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

(*b*) Unless otherwise specified, all pipe 2 in. and over in nominal diameter shall be furnished hot-finished followed by the treatment specified in Section 5.

(*c*) Unless otherwise specified, pipe under 2 in. in nominal diameter may be furnished either hot-finished or cold-drawn, with, where necessary, a suitable manufacturer's finishing treatment.

Discard

4. Sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Heat Treatment

5. The finished pipe shall be furnished in the normalized and drawn condition unless otherwise specified in the purchase order.

Chemical Composition

6. The steel shall conform to the following requirements as to chemical composition:

Identification Symbol[a]	P 1
Grade	Carbon-Molybdenum
Carbon, per cent	0.10 to 0.20
Manganese, per cent	0.30 to 0.60
Phosphorus, max., per cent	0.04
Sulfur, max., per cent	0.05
Silicon, per cent	0.10 to 0.50
Molybdenum, per cent	0.45 to 0.65

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[a] The similar alloy in the corresponding specifications for alloy-steel forgings and castings bears the number F 1 and C 1, respectively.

Ladle Analysis

7. A ladle analysis of each melt of steel shall be made by the steel manufacturer. The chemical composition thus determined, or that determined from a check analysis made by the pipe manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 6.

Check Analysis

8. (*a*) At the request of the purchaser's inspector, analyses as specified below shall be made by the manufacturer from the finished pipe and shall conform to the requirements specified in Section 6:

NOMINAL DIAMETER	NUMBER OF PIPE SELECTED
Under 2 in.	2 pipes from each lot of 400 lengths or fraction thereof
2 to 5 in., inclusive	2 pipes from each lot of 200 lengths or fraction thereof
9 in. and over	2 pipes from each lot of 100 lengths or fraction thereof

Results of these analyses shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 6.

(*b*) Drilling for analysis from pipe shall be taken from several points around each pipe selected for analysis. Drillings for analysis from billets shall be taken at a point midway between the outside and center of the billet by drilling parallel to the axis.

(*c*) If the analysis of one of the tests specified in Section 7 or Paragraph (*a*) of this section does not conform to the requirements specified in Section 6, analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

Tension Tests

9. (*a*) The material shall conform to the following minimum requirements as to tensile properties[a] at room temperature:

Tensile strength, min., lb. per sq. in.	55 000
Yield point, min., lb. per sq. in.	30 000
Elongation in 2 in., min., per cent	30

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[a] For transverse tension tests the material shall conform to these minimum tensile requirements except that the elongation in 2 in. shall be 25 per cent.

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by the use of dividers or other approved method, at a crosshead speed not to exceed $\frac{1}{8}$ in. per min. Where a definite yield point is not exhibited, the yield strength, corresponding to a limiting permanent set of 0.2 per cent of the gage length of the specimen, shall be reported instead. The "offset method" of determining yield strength as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[1] shall be followed. The tensile strength shall be determined at a crosshead speed not to exceed $1\frac{1}{2}$ in. per min.

Hydrostatic Tests

10. (*a*) Unless otherwise mutually agreed upon between the manufacturer and the purchaser, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress of 50 per cent of the minimum specified yield point at room temperature. This pressure shall be determined by the formula:

$$P = \frac{2St}{D}$$

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

where P = the minimum hydrostatic test pressure in pounds per square inch,
S = 0.50 times the minimum specified yield point at room temperature in pounds per square inch,
t = the nominal wall thickness in inches, and
D = the outside diameter in inches.

(*b*) The maximum hydrostatic test pressure shall not exceed 2500 lb. per sq. in. for sizes 3 in. or under in outside diameter, nor 4500 lb. per sq. in. for sizes over 3 in. to but not including 8⅝ in. in outside diameter and 3000 lb. per sq. in. for all sizes 8⅝ in. or over in outside diameter. The hydrostatic pressure shall be maintained for not less than 5 sec.

Flattening Tests

11. For pipe over 2 in. in nominal diameter, a section of pipe not less than 2½ in. in length shall be flattened between parallel plates until the opposite walls of the pipe meet. No cracks or breaks in the metal shall occur until the distance between the plates is less than one-half the outside diameter of the pipe, but in no case less than seven times the thickness of the pipe wall. Evidence of laminations or burnt material shall not develop during the entire flattening process.

Bend Tests

12. For pipe 2 in. or under in nominal diameter, a sufficient length of pipe shall stand being bent cold through 90 deg. around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180 deg. around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

Test Specimens

13. (*a*) Specimens cut either longitudinally or transversely shall be acceptable for tension tests.

(*b*) Longitudinal tension tests may be made in full section of the pipe up to the capacity of the testing machine. For larger sizes, the tension test specimens shall consist of strips cut from the pipe. The width of these specimens shall be 1½ in. and shall have a gage length of 2 in. When the pipe wall thickness exceeds ¾ in., the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Longitudinal tension specimens shall not be flattened between gage marks. The sides of specimens shall be parallel between gage marks.

(*c*) The transverse tension test may be made on pipe 8 in. and over in nominal diameter. Specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. The specimen shall consist of a strip cut transversely from the pipe; the width of the specimen shall be 1½ in. and its gage length 2 in. When the pipe wall thickness exceeds ¾ in. the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Specimens shall be flattened hot and heat treated in the same manner as the pipe, and shall be parallel between gage marks. At the option of the manufacturer, the transverse tension test specimen may be machined off on either surface provided not over 15 per cent of the nominal thickness is removed from either side.

NOTE.—The standard tension test specimens are described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

(*d*) Test specimens for flattening and bend tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except whem made on crop ends.

(*e*) All routine check tests shall be made at room temperature.

Number of Tests

14. (*a*) Tests shall be made as follows on one pipe from each heat-treated lot, but in no case on less than 5 per cent of the pipe ordered. Results of these tests shall be reported to the purchaser or his representative:

One transverse or longitudinal tension test specified in Section 9.

The flattening test specified in Section 11 for pipe over 2 in. in nominal diameter.

The bend test specified in Section 12 for pipe 2 in. or under in nominal diameter.

(*b*) For material heat treated by the continuous process, the tests specified in Paragraph (*a*) shall be made on each pipe in a lot constituting 5 per cent of the pipe ordered, but on not less than two pipes.

(*c*) Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

Retests

15. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 9, 11, or 12, retests shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

(*b*) If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than ¾ in. from the center of the gage length of the specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

(*c*) If any specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

Retreatment

16. If individual lengths of pipe selected to represent any lot fail to meet the test requirements specified in Sections 9, 11, or 12, the lot may be heat treated again and resubmitted for test, except that any individual lengths which meet the test requirements before retreating will be acceptable.

Permissible Variations in Weight and Dimensions

17. (*a*) *Weight.*—The weight of any length of pipe in sizes up to and including 12 in. shall not vary more than 3.5 per cent under and 6.5 per cent over that specified. For sizes over 12 in. the weight of any length shall not vary more than 5 per cent under and 10 per cent over that specified. Unless otherwise mutually agreed upon between the manufacturer and the purchaser, pipe in sizes smaller than 4 in. may be weighed in convenient lots; pipe in sizes 4 in. and larger shall be weighed separately.

(*b*) *Diameter.*—Variations in outside diameter shall not exceed those shown in the following table:

NOMINAL DIAMETER	PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER UNDER	OVER
$\frac{1}{8}$ to $1\frac{1}{2}$ in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{64}$ in. (0.015 in.)
2 to 4 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{32}$ in. (0.031 in.)
5 to 8 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{16}$ in. (0.062 in.)
10 to 18 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{3}{32}$ in. (0.093 in.)
20 to 24 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{8}$ in. (0.125 in.)

(*c*) *Thickness.*—The minimum wall thickness at any point shall not be more than 12.5 per cent under the nominal wall thickness specified.

(*d*) *Length.*—Pipe lengths shall be in accordance with the following regular practice:

> The lengths required shall be specified in the order. No pipe shall be under the specified length and not more than $\frac{1}{4}$ in. over that specified.
>
> No jointers are permitted unless otherwise specified.

Ends

18. Unless otherwise specified, pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

Finish

19. (*a*) The finished pipe shall be reasonably straight and free from injurious defects, and shall have a workmanlike finish.

Depth of Injurious Defects

(*b*) When the depth of defect in the pipe encroaches on the minimum wall thickness (87.5 per cent of the nominal thickness), or is in excess of 12.5 per cent of the nominal wall thickness, such defects shall be considered injurious.

Machining or Grinding Defects

(*c*) Pipe showing moderate slivers may be machined or ground inside or outside to a depth which shall insure the removal of all included scale and slivers, providing the wall thickness is not reduced below the minimum wall thickness required in these specifications. Machining or grinding shall follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

Repair by Welding

(*d*) Repair of injurious defects shall be permitted only subject to the approval of the purchaser and with the further understanding that the composition of the welding rod shall be suitable for the composition of the metal being welded. Welding of injurious defects in no case shall be permitted when the depth of defect exceeds 33⅓ per cent of the nominal pipe wall thickness or the length of repair exceeds 25 per cent of the nominal diameter of the pipe. Defects shall be thoroughly chipped out before welding, and then heat treated in accordance with Section 5. Each length of repaired pipe shall be retested hydrostatically in accordance with Section 10.

Marking

20. Each length of pipe manufactured in accordance with these specifications shall be legibly marked, either by stenciling, stamping, or rolling, with the manufacturer's private identifying mark, together with the symbols A 206 and the alloy symbol (as A 206 - P1) and an additional S if pipe meets the supplementary requirements specified in Paragraphs S1 to S7. Marking shall be within 12 in. of one end of each length. On pipe sizes 4 in. and larger, the weight shall be given. On small diameter pipe which is bundled, the above information may be legibly stamped on a metal tag securely attached to each bundle. When pipe marked as specified in this section is rejected, the designation A 206 shall be canceled.

Inspection

21. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment and at the manufacturer's expense, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. The manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacture or tests that may be desired.

Rejection

22. Each length of pipe which develops injurious defects in shop working or application shall be rejected, and the manufacturer shall be notified. No rejections under these or any other specifications, shall be marked as specified in Section 20 for sale under these specifications except where such pipe fails to comply with the weight requirements alone, in which case it may be sold under the weight specifications with which it does comply.

(See Supplementary Requirements, page (584.)

SUPPLEMENTARY REQUIREMENTS FOR SEAMLESS PIPE FOR USE IN CENTRAL STATIONS AT PRESSURES OF 400 LB. PER SQ. IN., OR OVER, AND TEMPERATURES OF 750 F. TO 1000 F., OR OTHER APPLICATIONS WHERE A SUPERIOR GRADE OF PIPE IS REQUIRED

S1. These requirements shall not be considered unless specified in the order, in which event the supplementary tests shall be made at the mill, unless otherwise agreed upon, at the purchaser's expense and witnessed by his inspector before shipment of the material.

Check Analysis

S2. Check analysis may be made on any length of pipe. Individual lengths failing to meet the chemical requirements specified in Section 6 shall be rejected.

Transverse Tension Tests

S3. Transverse tension tests may be made on specimens from both ends of each length of pipe. If the specimen from either end of any length fails to meet the physical properties specified in Section 9, that length shall be rejected.

Flattening Tests

S4. The flattening tests specified in Section 11 may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to meet the specified requirements, that length shall be rejected.

Finish and Metal Structure

S5. The finished pipe shall be free from all immoderate slivers and depressions. The steel shall have a homogeneous structure as shown by the etching test in Paragraph S6.

Etching Tests

S6. Etching tests[1] may be made on sections from any pipe, and shall show sound and reasonably uniform material, free from injurious laminations, cracks and similar objectionable defects. Sections used for the flattening tests described in Section 11 may be used for the etching test. If the specimen from any length shows objectionable defects, that length may be rejected.

Rejection

S7. At the purchaser's discretion, if 10 per cent of the pipe in any one lot fail to conform to the requirements of Paragraphs S2 to S6, the entire lot may be rejected. Rejection of a lot shall be based on tests from not less than two pipes. A lot shall consist of all the pipe bought by a purchaser of the same size and wall thickness from any one heat.

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[1] Pending development of etching methods applicable to the product covered by these specifications, it is recommended the Tentative Recommended Practice for a Macro-Etch Test for Steel described in the *Metals Handbook*, Am. Soc. for Metals, 1936 edition, p. 573, be followed.

EXPLANATORY NOTE

NOTE.—Pending the incorporation of high-temperature data in an appendix, which it is the purpose in due time to add, high-temperature properties, when it is desired that the same be indicated or specified, shall be a matter of agreement between the manufacturer and the purchaser. No high-temperature tests shall be required on the materials selected unless a matter of agreement between the manufacturer and the purchaser. When required, the short-time tests at elevated temperature shall be in accordance with the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 21 – 37 T)[1] and the creep tests shall be in accordance with the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 22 – 38 T)[2] of the American Society for Testing Materials.

APPENDIX

The following sizes and wall thicknesses of carbon-molybdenum pipe as provided for in these specifications were agreed on as standard for stock purposes by the pipe manufacturers and the Prime Movers Committee of the Edison Electric Institute. These data are included here for information only.

	SERVICE UP TO 1400 LB. PER SQ. IN. AT 950 F.		SERVICE UP TO 900 LB. PER SQ. IN AT 900 F.	
NOMINAL PIPE SIZE, IN.	SCHEDULE NO.	THICKNESS, IN.	SCHEDULE NO.	THICKNESS, IN
$\frac{3}{4}$	160	0.218	160	0.218
$1\frac{1}{4}$	160	0.250	160	0.250
$2\frac{1}{2}$	160	0.375	160	0.375
4	160	0.531	120	0.437
6	160	0.718	120	0.562
8	160	0.906	100	0.593
10	160	1.125	100	0.718
12	160	1.312	100	0.843
14	160	1.406	100	0.937
16	160	1.562	100	1.031

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1290 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1654.

[2] See p. 1301.

TENTATIVE SPECIFICATIONS
FOR
NORMALIZED QUENCHED-AND-TEMPERED ALLOY-STEEL FORGINGS[1]

A.S.T.M. Designation: A 63 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) These specifications cover different classes of alloy-steel forgings now commonly used in the normalized, quenched-and-tempered condition in locomotive and car construction, in diesel engines, for miscellaneous machinery parts on ships, locks and dams, in small turbines, etc.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for forgings for locomotive main and side rods, straps, also piston rods, hammer rams, etc.

Class B, for forgings for locomotive driving and trailing-truck axles, piston rods, crank pins, diesel engine crankshafts, eccentric shaft pins, etc.

Class C, for forgings for retainer rings, smooth running drive shafts, crankshafts, etc.

Process

2. The steel shall be made by either or both the following processes; open-hearth or electric-furnace.

Discard

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests

4. The number and location of prolongations provided for test shall be agreed upon by the purchaser and the manufacturer. Unless otherwise specified, at least 20 per cent of the forgings shall be provided with prolongations or by agreement, a forging may be used for test purposes.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These tentative specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars (A 63 – 36), 1936 Book of A.S.T.M. Standards, Part I, p. 202.

Boring

5. (*a*) All forgings over 10 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring and rough-turning shall be done before quenching.

(*b*) If boring is required, the diameter of the hole shall be so balanced with respect to the outside diameter as to provide effective cooling surfaces for heat treatment.

Heat Treatment

6. (*a*) *Cooling After Forging.*—The forgings shall be allowed to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. If specified, forgings shall be annealed or normalized after cooling from the forging heat and before they are machined and given a reheating for quenching.

(*b*) *Annealing.*—If an annealing treatment is applied, the forgings shall be uniformly reheated to the proper temperature to refine the grain and allowed to cool uniformly in the furnace, at least to a temperature at which color is no longer visible, or in some other environment in which the rates of cooling will be appreciably less than those observed in still air. A group of forgings thus heated and cooled shall be known as an "annealing charge."

(*c*) *Normalizing.*—The forgings shall be uniformly reheated to a proper temperature to refine the grain and after being held a sufficient length of time at this temperature shall be withdrawn from the furnace and allowed to cool uniformly in still air, protected from rain or snow, to a temperature below the critical range. A group of forgings thus heated shall be known as a "normalizing charge."

(*d*) *Quenching.*—After the cooling from normalizing, the forgings shall be uniformly reheated to the proper temperature to refine the grain and quenched in a suitable liquid medium under substantially uniform conditions. A group thus reheated shall be known as a "quenching charge."

(*e*) *Tempering.*—For tempering, after quenching as described in Paragraph (*d*), the forgings shall be uniformly reheated to a temperature below the critical range and after being held a proper time at this temperature shall be cooled uniformly. A group of forgings thus treated shall be known as a "tempering charge."

Chemical Composition

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

	ACID	BASIC
Phosphorus, max., per cent	0.05	0.04
Sulfur, max., per cent	0.05	0.05

(*b*) The ranges in composition of alloy steel, other than phosphorus and sulfur, shall be agreed upon by the manufacturer and the purchaser.

Ladle Analysis

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in Section 7 including the alloys agreed upon. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

TABLE I.—MINIMUM TENSILE REQUIREMENTS FOR FORGINGS HAVING A MAXIMUM OUTSIDE DIAMETER OR THICKNESS OF NOT OVER 10 IN. WHEN SOLID OR NOT OVER 20 IN. WHEN BORED.

Class	Size	Tensile Strength, min., lb. per sq. in.	Extensometer Yield Point, min., lb. per sq. in.	Elongation in 2 in., min., per cent	Reduction of Area, min., per cent
A Alloy Steel, Quenched and Tempered	Up to 7 in. in outside diameter or thickness, $3\frac{1}{2}$ in. max. wall..........................	95 000	70 000	25	55
	Over 7 to 10 in. in outside diameter or thickness, 5 in. max. wall......................	90 000	65 000	22	50
	Outside diameter or thickness not over 20 in., 5 to 8 in. wall..........................	85 000	60 000	22	50
B Alloy Steel, Quenched and Tempered	Up to 7 in. in outside diameter or thickness, $3\frac{1}{2}$ in. max. wall..........................	105 000	80 000	21	50
	Over 7 to 10 in. in outside diameter or thickness, 5 in. max. wall......................	100 000	75 000	19	50
	Outside diameter or thickness not over 20 in., 5 to 8 in. wall..........................	95 000	70 000	19	50
C Alloy Steel, Quenched and Tempered	Up to 4 in. in outside diameter or thickness....	120 000	95 000	18	50
	Over 4 to 7 in. in outside diameter or thickness, $3\frac{1}{2}$ in. max. wall....................	120 000	95 000	16	50
	Over 7 to 10 in. in outside diameter or thickness, 5 in. max. wall......................	115 000	90 000	16	50

Check Analysis

9. An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified and agreed upon in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

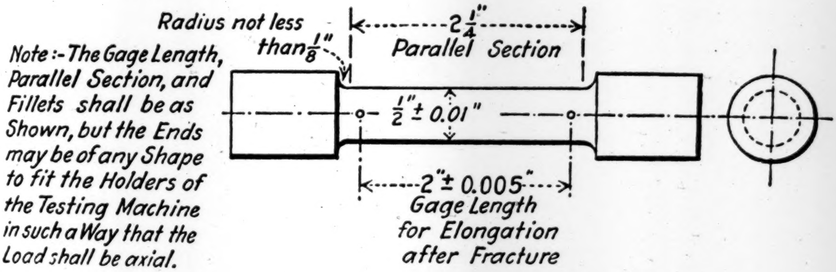
Tension Tests

10. (*a*) The forgings shall conform to the requirements as to tensile properties specified in Table I.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The extensometer yield point prescribed in these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.


Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Bend Tests

11. If specified by the purchaser, bend tests shall be made as follows:

(*a*) For the first class by size, the test specimen shall stand being bent cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*b*) For the second and third classes by size, the test specimen shall stand being bent cold through 180 deg. around a pin 1½ in. in diameter, without cracking on the outside of the bent portion.

Proof Tests

12. When specified by the purchaser, forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.[1]

Test Specimens

13. (*a*) Tension and bend test specimens shall be taken from a full size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging

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[1] For information relative to proof tests of finished forgings, see Appendix.

back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser. In the latter case, means shall be provided to avoid injury to the specimen by overstressing.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be $\frac{1}{2}$-in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests

14. (*a*) One tension and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension and, if specified, one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension and, if specified, one bend test from a forging of each class by size shall be made as specified in Sections 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension test specimen is less that that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

15. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made in accordance with Section 14.

(*b*) If the fracture of any tension test specimen shows over 15 per cent crystalline, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystalline, the forgings represented by such specimen shall be retempered or requenched and tempered. The fracture shall be considered crystalline if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

Workmanship

16. The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts, and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance sufficient to permit finish-machining to the required dimensions in clean metal. In centering, 60-deg. centers with clearance drilled for points shall be used.

Finish

17. The forgings shall be free from injurious defects and shall have a workmanlike finish.

Marking

18. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

Inspection

19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing

21. Samples tested in accordance with Section 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX

As a guide in deciding on a proof test for quenched-and-tempered forgings, the following particulars regarding three established methods of testing are given.[1] These methods of proof testing are giving satisfactory results in practice.

The practices followed by two companies, designated Practice A, require that all axles, shafts and similar forgings shall undergo an impact proof test on an A. A. R. drop-test machine, with supports spaced 3 ft. center to center, two blows being struck with a tup weighing 1640 or 2240 lb. The forging is to have one of the points of support as near as practicable to one end for the first blow and as near as practicable to the other end for the second blow, the forging being turned 90 deg. on its longitudinal axis after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas:

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS

Diameter, in.	PRACTICE A Supports 3 ft. Center to Center Carried on A.A.R. Drop-Test Machine				PRACTICE B Rigid supports 5 ft. Center to Center PRACTICE C Rigid supports at Ends of Forgings
	Height of Drop of 1640-lb. Tup		Height of Drop of 2240-lb. Tup		Energy of Blow, ft-lb.
	ft.	in.	ft.	in.	
4½	0	11	....	....	700
5	1	3	....	....	900
5½	1	8	1	2	1 200
6	2	2	1	7	1 700
6½	2	9	2	0	2 500
7	3	5	2	6	3 500
7½	4	3	3	1	4 700
8	5	1	3	8	6 000
8½	6	2	4	6	7 500
9	7	3	5	3	9 000
9½	8	7	6	3	10 000
10	10	0	7	4	11 000
10½	11	7	8	6	12 000
11	13	5	9	10	13 000
11½	15	3	11	1	14 000
12	17	4	12	8	15 000

$$\text{For the 1640-lb. tup: } H = 0.01\,D^3$$
$$\text{For the 2240-lb. tup: } H = 0.0073\,D^3$$

where H = the height of drop in feet, and
D = the diameter of the forging at the center in inches.

The practices followed by two other companies, designated Practices B and C, require that forgings shall be submitted to an impact proof test by having them carried on rigid supports and struck one blow at the center by a tup delivering the number of foot-pounds of energy shown in the accompanying table. In Practice B the supports are spaced 5 ft. center to center, while in Practice C the supports are placed as near as practicable to the ends of the forgings.

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[1] For more detailed information concerning these methods of proof testing, see report of Committee A-1 on Steel, Appendix IV, "Report on Proof Tests of Finished Forgings," *Proceedings*, Am. Soc. Testing Mats., Vol. XIV, Part I, p. 120 (1914); also, Report of Committee A-1 for 1917, *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part I, pp. 115–117 (1917).

TENTATIVE SPECIFICATIONS
FOR
CORROSION-RESISTING CHROMIUM-NICKEL STEELS (SHEET, STRIP AND PLATE)[1]

A.S.T.M. Designation: A 167 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover soft corrosion-resisting chromium-nickel steel sheet, strip and plate. The terms sheet, strip and plate as used in these specifications apply to the following:

Sheet includes products less than $\frac{3}{16}$ in. in thickness and 24 in. and over in width.

Strip includes both hot-rolled and cold-rolled strip as follows:

- *Cold-Rolled Strip* includes material under 24 in. in width.
- *Hot-Rolled Strip* includes material 0.175 in. and less in thickness and under 24 in. in width.

Plate includes material $\frac{3}{16}$ in. and over in thickness.

MANUFACTURE

Process

2. The steel shall be made by the following processes: electric-arc, electric-induction, or other approved processes.

Discard

3. A sufficient discard shall be made from each ingot to insure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

	Type Number	Carbon, per cent	Manganese, max., per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, per cent	Chromium, min., per cent	Nickel, min., per cent
Grade 1	302	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	17.50	8.00
Grade 2	304	0.08 max.	1.50	0.035	0.030	0.75 max.	17.50	8.00
Grade 3	305	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	18.00	9.00
Grade 4	306	0.08 max.	1.50	0.035	0.030	0.75 max.	18.00	9.00
Grade 5[a]	321	0.10 max.	1.50	0.035	0.030	0.75 max.	17.00	8.00
Grade 6[b]	316	0.08 max.	2.00	0.035	0.030	0.75 max.	16.00	10.00
Grade 7	309	0.20 max.	1.50	0.035	0.030	3.50 max.	12.00	12.00
Grade 8	310	0.25 max.	1.50	0.035	0.030	2.00 max.	22.00	19.00
Grade 9[c]	347	0.10 max.	1.50	0.035	0.030	0.75 max.	17.00	8.00
Grade 10	302—B	0.08 to 0.20[d]	1.50	0.035	0.030	2.00 min.	17.50	8.00
Grade 11	301—X	0.08 to 0.20[d]	1.50	0.035	0.030	0.75 max.	16.00	7.00

[a] Grade 5 shall have a minimum titanium content of four times the carbon content.
[b] Grade 6 shall have a molybdenum content of 2.00 to 4.00 per cent.
[c] Grade 9 shall have a minimum columbium content of ten times the carbon content.
[d] The carbon content may be specified 0.12 per cent, maximum, for Grades 1, 3, 10, and 11.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. The analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. If check analysis is specified by the purchaser, it shall be made from drillings or millings as taken from the finished material or from a broken test specimen. The chemical composition thus determined shall conform to the requirements specified in Section 4.

PHYSICAL PROPERTIES AND TESTS

7. (*a*) When specified by the purchaser, the material shall conform to the following requirements as to physical properties:

	Tensile Strength, min., lb. per sq. in.	Yield Point, min., lb. per sq. in.	Elongation in 2 in., min., per cent	Hardness		Cold Bend,[a] deg.
				Brinell, max.	Rockwell (B Scale, 100-kg. load, $\frac{1}{16}$-in. ball), max.	
Grade 1	80 000	30 000	40.0	202	88	180
Grade 2	80 000	30 000	40.0	202	88	180
Grade 3	80 000	30 000	40.0	202	88	180
Grade 4	80 000	30 000	40.0	202	88	180
Grade 5	80 000	35 000	40.0	202	88	180
Grade 6	85 000	40 000	40.0	217	95	180
Grade 7	90 000	40 000	40.0	217	95	180
Grade 8	90 000	40 000	40.0	217	95	180

[a] See Section 8.

(*b*) The yield point shall be determined by the dividers method.

Bend Tests

8. (*a*) The bend test specimens shall stand being bent cold through the required angle without cracking on the outside of the bent portion.

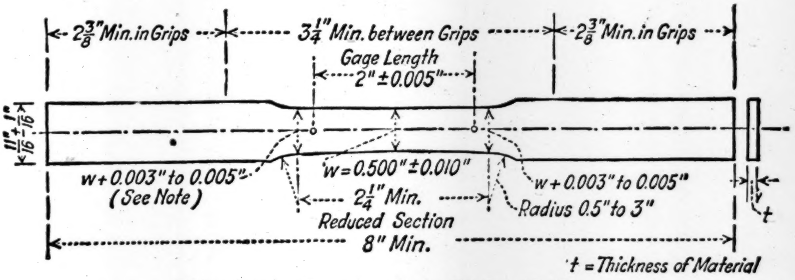
(*b*) Material up to and including $\frac{3}{8}$ in. in thickness shall be bent around a pin the diameter of which is equal to the thickness of the material.

(*c*) Plates $\frac{3}{8}$ in. and over in thickness shall be bent around a pin the diameter of which is equal to twice the thickness of the material.

(*d*) Axis of the bends shall be parallel to the direction of rolling.

Test Specimens

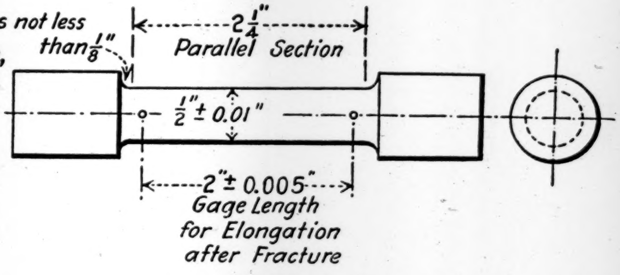
9. (*a*) Tension test specimens shall be taken from finished material and shall be in the longitudinal direction. The tension specimens shall be of the full thickness of the material and shall conform to the dimensions shown in Fig. 1, except for plates $\frac{3}{4}$ in. and over in thickness, in which case the test specimens shall be machined to the form and dimensions shown in Fig. 2.


2$\frac{3}{8}$" Min. in Grips
3$\frac{1}{4}$" Min. between Grips
2$\frac{3}{8}$" Min. in Grips
Gage Length
2" ± 0.005"
$\frac{11}{16}$" ± $\frac{1}{16}$"
w + 0.003" to 0.005"
(See Note)
w = 0.500" ± 0.010"
2$\frac{1}{4}$" Min.
Reduced Section
w + 0.003" to 0.005"
Radius 0.5" to 3"
t
8" Min.
t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.
All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet and Strip Metals.


Radius not less than $\frac{1}{8}$"
2$\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Bend test specimens from sheet and strip less than $\frac{3}{16}$ in. in thickness shall be the full thickness and shall have a width equal to six times the thickness but not less than 1 in. The length shall be equal to the width of the sheet or strip, but in no case longer than 12 in. The edges of the test specimens may be rounded to a radius equal to one-half the thickness.

(*c*) Bend test specimens taken from plates shall be of the full thickness of the material up to and including $\frac{1}{2}$ in. in thickness, of a suitable length, and between 1 and 2 in. in width. The sheared edges shall be removed to a depth of at least $\frac{1}{8}$ in. and the sides shall be smoothed with a file. The corners of the cross-section of the specimen may be broken with a smooth file, but no appreciable rounding of corners will be permitted. In the case of plates over $\frac{1}{2}$ in. in thickness, machined specimens as described in Paragraph (*d*) shall be used.

(*d*) Machined bend test specimens shall be 1 by $\frac{1}{2}$ in. in cross-section and at least 6 in. in length. The edges may be rounded to a $\frac{1}{16}$-in. radius. When permitted by agreement between the purchaser and the manufacturer, the cross-section may be modified to $\frac{1}{2}$-in. square. The center of the cross-section of the test specimen shall be half way between the center and outer surface of the plate, unless otherwise specified.

(*e*) Hardness tests may be made on the ends of the tension specimens, as far as possible from the gage length, before they are subjected to the tension test.

Number of Tests

10. Two tension tests, two hardness tests and one bend test shall be taken from each lot of material, a lot consisting of 100 or less each of sheets, strips or plates, and in no case less than 1000 lb. from the same melt of steel and the same specified thickness.

Special Tests

11. If any special tests are required which are thought to be pertinent to the intended application of the material ordered, they shall be as agreed upon between the purchaser and the manufacturer.

Physical Tests

12. In making physical tests reference should be made to the following methods of test of the American Society for Testing Materials:

(*a*) *Tension Tests.*—Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8).[1]

(*b*) *Brinell Hardness.*—Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10).[2]

(*c*) *Rockwell Hardness.*—Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18).[3]

FINISH

Designation of Finish for Sheets

13. The various types of finish procurable on sheet products shall be as follows:

No. 1. Hot rolled, annealed and pickled.
No. 2D. Full finish (Dull).
No. 2B. Full finish (Bright cold rolled).
No. 4. Standard polish, one or both sides.
No. 6. Standard polish, Tampico brushed, one or both sides.
No. 7. High lustre finish.
No. 8. Mirror finish.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.
[2] *Ibid.*, p. 817.
[3] *Ibid.*, p. 824.

Explanation of Finish:

No. 1. For parts which require no further finishing—for oxidation or scale resistance.

No. 2D. Similar to No. 1, except slightly better finish due to cold rolling. For deep-drawn articles which are polished subsequent to fabrication.

No. 2B. Slightly harder temper than No. 1 and No. 2D, hence should not be used for exceptionally difficult deep-drawing work. This finish lends itself better to polishing than No. 1 or No. 2D.

TABLE I.—DIMENSIONAL AND WEIGHT TOLERANCES OF STANDARD SHEET.

No. 1 and No. 2 Finishes.
Weight Tolerances Only to Apply on Polished Finishes.

THICKNESS TOLERANCES

Ordered Thickness, in.	Tolerance, Plus or Minus, in.
0.005	0.001
0.006 to 0.007	0.0015
0.008 to 0.0160	0.002
0.0161 to 0.026	0.003
0.027 to 0.040	0.004
0.041 to 0.058	0.005
0.059 to 0.072	0.006
0.073 to 0.083	0.007
0.084 to 0.098	0.008
0.099 to 0.114	0.009
0.115 to 0.130	0.010
0.131 to 0.145	0.012
0.146 to 0.176	0.014

WIDTH AND LENGTH TOLERANCES[a]

Width	Tolerance	
	Plus	Minus
Up to 42 in.	$\frac{1}{16}$ in.	0
42 in. and over	$\frac{1}{8}$ in.	0
Length		
Up to 120 in.	$\frac{1}{16}$ in.	0
120 in. and over	$\frac{1}{8}$ in.	0

WEIGHT TOLERANCES

The actual weight of any one item of an ordered thickness and size in any finish is limited in overweight by the following tolerances:

	Tolerance Actual Weight Over the Estimated Weight[b]
Any item of 5 sheets or less, or any item estimated to weigh 200 lb. or less	10 per cent
Any item of more than 5 sheets, and estimated to weigh more than 200 lb.	7½ per cent

There is no under tolerance in weight for No. 1 and No. 2 finishes, these finishes being limited in under tolerance only by the permissible variations in thickness. Polished sheets may actually weigh as much as 5 per cent less than the estimated weight.[b]

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[a] Sheet 0.131 in. and over in thickness, regardless of size, may have permissible variations of ±$\frac{1}{4}$ in. in width and in length, respectively.

[b] For determining estimated weight the following factor shall be used:
Chromium-nickel stainless steel sheets.......... 42.0 lb. per sq. ft. per inch thickness

No. 4. For use where a polished finish is demanded. It is used for such equipment as dairy and ice cream tanks, soda fountains, meat packing and food equipment, architectural and building construction, etc.

No. 6. Tampico brushing of the No. 4 finish results in a satin finish with lower reflectivity than No. 4 finish. For building construction and ornamentation where a brighter finish is undesirable—for use in conjunction with bright finish No. 4, No. 7 and No. 8 as contrasts.

No. 7. The buffing of No. 4 finish results in a sheet with a high degree of lustre, but in which all the grit lines are not removed. It is used for trim for cabinets—for a contrast with other finishes.

No. 8. The highest degree of polish commercially available. Grit lines and scratches have been removed. This finish is suitable for press plates as used in the laminated paper and fibrous products industry—for mirrors and reflectors.

Designation of Finish for Strip

14. The various types of finish procurable on strip products shall be as follows:

(*a*) *Cold-Rolled Strip:*

No. 1. Annealed and pickled.

No. 2. Annealed, pickled and rerolled.

TABLE II.—THICKNESS TOLERANCES OF COLD-ROLLED STRIP.

Thickness tolerances are based on measurements taken $\frac{3}{8}$ in. in from the edge on cold-rolled strip 1 in. or over in width, and at any place on the strip on material less than 1 in. in width.

Tolerances given are in inches and all are plus or minus.

Ordered Thickness, in.	Width									
	Under $\frac{1}{2}$ to $\frac{3}{16}$ in., incl.	Under 1 to $\frac{1}{2}$ in., incl.	Under $1\frac{1}{2}$ to 1 in., incl.	Under 3 to $1\frac{1}{2}$ in., incl.	3 to 6 in., incl.	Over 6 to 9 in., incl.	Over 9 to 12 in., incl.	Over 12 to 16 in., incl.	Over 16 to 20 in., incl.	20 to $23\frac{15}{16}$ in., incl.
0.249 to 0.161, incl.	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.005	0.006	0.006
0.160 to 0.100, incl.	0.002	0.002	0.002	0.002	0.003	0.004	0.004	0.004	0.005	0.005
0.099 to 0.069, incl.	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004
0.068 to 0.050, incl.	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004
0.049 to 0.040, incl.	0.002	0.002	0.002	0.002	0.0025	0.003	0.003	0.003	0.004	0.004
0.039 to 0.035, incl.	0.002	0.002	0.002	0.002	0.0025	0.003	0.003	0.003	0.003	0.003
0.034 to 0.032, incl.	0.0015	0.0015	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
0.031 to 0.029, incl.	0.0015	0.0015	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
0.028 to 0.026, incl.	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002	0.002	0.0025	0.003
0.025 to 0.023, incl.	0.001	0.001	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
0.022 to 0.020, incl.	0.001	0.001	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
0.019 to 0.017, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.002	0.002	0.002
0.016 to 0.015, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
0.014 to 0.013, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
0.012	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.0015
0.011	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015
0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015
0.009 to 0.006, incl.	0.00075	0.00075	0.00075	0.00075	0.00075	......	......	......	......	......
Under 0.006	0.00050	0.00050	0.00050	0.00050	0.00050	......	......	......	......	......

(*b*) *Hot-Rolled Strip:*

No. 1. Hot rolled, annealed and pickled.

Explanation of Finish:

No. 1. For parts requiring maximum amount of deep drawing, for oxidation resistance.

No. 2. Slightly harder temper than No. 1, finish due to extra cold rolling. Very good surface.

Designation of Finish for Plates

15. The various types of finish procurable on plates shall be as follows:

No. 1. Hot rolled, annealed and either pickled or sand blasted and pickled.

No. 4. Standard polish (limitation on width).

PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHT

Sheet Tolerances

16. The material referred to as sheet shall conform to the dimensional and weight tolerances indicated in Table I.

Strip Tolerances

17. (*a*) *Cold-Rolled Strip.*—The material referred to as cold-rolled strip shall conform to the dimensional tolerances indicated in Tables II and III.

(*b*) *Hot-Rolled Strip.*—The material referred to as hot-rolled strip shall conform to the dimensional tolerances indicated in Table IV.

TABLE III.—DIMENSIONAL TOLERANCES OF COLD-ROLLED STRIP.

WIDTH TOLERANCES, NOS. 1, 4, 5, AND 6 EDGES

Edge	Edge Description	Width, in.	Thickness, in.	Tolerance in Width, plus or minus, in.
No. 1	Round or square edge, rolled	$\frac{9}{32}$ or under	$\frac{1}{16}$ or under	0.005
No. 1		over $\frac{9}{32}$ to $\frac{3}{4}$, incl	$\frac{3}{32}$ or under	0.005
No. 1		over $\frac{3}{4}$ to 5, incl.	$\frac{1}{8}$ or under	0.005
No. 5	Square rolled or filed after slitting	$\frac{9}{32}$ or under	$\frac{1}{16}$ or under	0.005
No. 5		over $\frac{9}{32}$ to $\frac{3}{4}$, incl	$\frac{3}{32}$ or under	0.005
No. 5		over $\frac{3}{4}$ to 5, incl	$\frac{1}{8}$ or under	0.005
No. 5		over 5 to 9, incl	$\frac{1}{8}$ to 0.008, incl	0.010
No. 5		over 9 to 20, incl	0.105 to 0.015	0.010
No. 5		over 20 to 23$\frac{15}{16}$, incl	0.080 to 0.023	0.015
No. 6	Square edge, rolled	$\frac{1}{2}$ or under	$\frac{3}{16}$ or under	0.010
No. 6		over $\frac{1}{2}$ to $\frac{15}{16}$, incl	$\frac{3}{16}$ to 0.025, incl	$\frac{1}{64}$
No. 6		over $\frac{15}{16}$ to 2, incl	$\frac{1}{4}$ to 0.025, incl	$\frac{1}{32}$
No. 6		over 2 to 6, incl	$\frac{1}{4}$ to 0.025, incl	$\frac{3}{64}$

WIDTH TOLERANCES,[a] NO. 3 EDGE

Thickness, in.	Widths			
	Up to 2 in.	Over 2 to 6 in.	Over 6 to 12 in.	Over 12 to 24 in., excl.
0.050 or under	0.007	0.010	0.015	0.015
0.051 to 0.083	0.010	0.012	0.015	0.020
0.084 or over	0.012	0.015	0.018	0.020

LENGTH TOLERANCES

Length, ft.	Tolerance, in.
Up to 5, incl	$+\frac{3}{8}$
Over 5 to 10, incl	$+\frac{1}{2}$
Over 10 to 20, incl	$+\frac{5}{8}$
Over 20 to 30, incl	$+\frac{3}{4}$
Over 30 to 40, incl	+1
Over 40 to 60, incl	$+1\frac{1}{2}$
Over 60 to 90, incl	+2
Over 90 to 200, incl	$+2\frac{1}{2}$

CAMBER TOLERANCES[b]

Up to and including $1\frac{1}{2}$ in. in width	$\frac{1}{2}$ in. in any 8-ft. length
Over $1\frac{1}{2}$ to 24 in. excl., in width	$\frac{1}{4}$ in. in any 8-ft. length

[a] Width tolerances shown are plus or minus. If variation is desired all one way, double the figure indicated.

[b] Camber shall be determined by placing an 8-ft. straight edge against the concave side of the strip.

Plate Tolerances

18. The material referred to as plate shall conform to the thickness and weight tolerances indicated in Table V.

Finish

19. The material shall be free from injurious defects, shall have a workmanlike appearance, and shall correspond to the designated finish as indicated in Sections 13, 14 and 15.

TABLE IV.—DIMENSIONAL TOLERANCES OF HOT-ROLLED STRIP.

THICKNESS TOLERANCES

Thickness	Width			
	Up to 5 in., incl.	Over 5 in. to 10 in., incl.	Over 10 in. to 15 in., incl.	Over 15 in. to $23\frac{15}{16}$ in. incl.
No. 23 to No. 18, incl.	+0.003 in.—0.003 in.	+0.004 in.—0.004 in.	....	....
No. 17 to No. 11, incl.	+0.004 in.—0.004 in.	+0.005 in.—0.005 in.	+0.006 in.—0.006 in.	+0.007 in.—0.007 in.
No. 10 to 0.187 in., incl.	+0.005 in.—0.005 in.	+0.006 in.—0.006 in.	+0.007 in.—0.007 in.	+0.008 in.—0.008 in.
0.188 to 0.249 in., incl.	+0.006 in.—0.006 in.	+0.007 in.—0.007 in.	+0.008 in.—0.008 in.	+0.009 in.—0.009 in

Thickness measurement shall be taken $\frac{3}{8}$ in. from edge of strip.

Tolerance for thickness at center measurement shall be that for the edge measurement plus:

0.001 in. for widths $\frac{1}{2}$ to $1\frac{1}{2}$ in.
0.002 in. for widths $1\frac{1}{2}$ to $2\frac{1}{2}$ in.
0.003 in. for widths $2\frac{1}{2}$ to 5 in.
0.004 in for widths 5 to 10 in.
0.005 in. for widths 10 to 15 in.
0.006 in. for widths 15 to $23\frac{15}{16}$ in.

WIDTH TOLERANCE

Width, in.	Tolerance, in.	
	Plus	Minus
Up to 1 in. by No. 16 B.w.g. and heavier	$\frac{1}{32}$	$\frac{1}{32}$
Up to 1 in. by No. 17 B.w.g. and lighter	$\frac{1}{32}$	$\frac{1}{32}$
Over 1 to 2, incl	$\frac{1}{32}$	$\frac{1}{32}$
Over 2 to 5, incl	$\frac{3}{64}$	$\frac{3}{64}$
Over 5 to 10, incl	$\frac{1}{16}$	$\frac{1}{16}$
Over 10 to 15, incl	$\frac{3}{32}$	$\frac{3}{32}$
Over 15 to 20, incl	$\frac{1}{8}$	$\frac{1}{8}$
Over 20 to $23\frac{15}{16}$, incl	$\frac{5}{32}$	$\frac{5}{32}$

LENGTH TOLERANCE

Length of Strip, ft.	Up to 3 in. in Width		Over 3 Up to 6 in. in Width		Over 6 in. in Width	
	Plus	Minus	Plus	Minus	Plus	Minus
Up to 5, incl	$\frac{1}{4}$ in.	0	$\frac{3}{8}$ in.	0	$\frac{1}{2}$ in.	0
Over 5 to 10, incl	$\frac{3}{8}$ in.	0	$\frac{1}{2}$ in.	0	$\frac{3}{4}$ in.	0
Over 10 to 20, incl	$\frac{1}{2}$ in.	0	$\frac{5}{8}$ in.	0	1 in.	0
Over 20 to 30, incl	$\frac{3}{4}$ in.	0	$\frac{3}{4}$ in.	0	$1\frac{1}{4}$ in.	0
Over 30 to 40, incl	1 in.	0	1 in.	0	$1\frac{1}{2}$ in.	0
Over 40	$1\frac{1}{2}$ in.	0	$1\frac{1}{2}$ in.	0	$1\frac{3}{4}$ in.	0

CAMBER TOLERANCE

Strip shall be as straight as practicable and not more than $\frac{1}{4}$ in. out of line in any 8 ft. of length, with camber measurement taken on the concave edge.

INSPECTION AND REJECTION

Inspection

20. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is in progress to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications except when an agreement has previously been made between the manufacturer and purchaser regarding the cost of such tests.

TABLE V.—STANDARD ROLLING TOLERANCES OF PLATES.

THICKNESS TOLERANCES[a]

All plates must be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. under the thickness ordered, and the overweight of each lot[b] in each shipment shall not exceed the amount given in the table below.

WEIGHT TOLERANCES[c]

Ordered Thickness, in.	Permissible Excess in Average Weight per Square Foot of Plates for Widths Given, Expressed in Percentage of Nominal Weight								
	Under 48 in.	48 in., incl., to 60 in., excl.	60 in., incl., to 72 in., excl.	72 in., incl., to 84 in., excl.	84 in., incl., to 96 in., excl.	96 in., incl., to 108 in., excl.	108 in., incl., to 120 in., excl.	120 in., incl., to 132 in., excl.	132 in., incl., to 144 in., excl.
$\frac{3}{16}$, incl., to $\frac{1}{4}$, excl.	10.5	12	13.5	15	18	....	....	....	....
$\frac{1}{4}$, incl., to $\frac{5}{16}$, excl.	9	10.5	12	13.5	15	18	21	24	28.5
$\frac{5}{16}$, incl., to $\frac{3}{8}$, excl.	7.5	9	10.5	12	13.5	15	18	21	25.5
$\frac{3}{8}$, incl., to $\frac{7}{16}$, excl.	7	7.5	9	10.5	12	13.5	15	18	22.5
$\frac{7}{16}$, incl., to $\frac{1}{2}$, excl.	6	7	7.5	9	10.5	12	13.5	15	19.5
$\frac{1}{2}$, incl., to $\frac{5}{8}$, excl.	5.5	6	7	7.5	9	10.5	12	13.5	16.5
$\frac{5}{8}$, incl., to $\frac{3}{4}$, excl.	4.5	5.5	6	7	7.5	9	10.5	12	13.5
$\frac{3}{4}$, incl., to 1, excl.	4	4.5	5.5	6	7	7.5	9	10.5	12
1, or over	4	4	4.5	5.5	6	7	7.5	9	10.5

[a] Spot grinding is permitted to remove surface imperfections not to exceed 0.01 in. under the specified thickness.

[b] The term "lot" means all of the plates of each group width and each group thickness.

[c] The weight of individual plates shall not exceed the nominal weight by more than one and one-third times the amount given in the above table.

Rejection

21. (*a*) Unless otherwise specified, any rejection based on tests in accordance with these specifications shall be reported within 10 days from date of test.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works shall be rejected and the manufacturer shall be notified.

Rehearing

22. Samples tested in accordance with this specification, which represent rejected material, shall be preserved three weeks from date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a hearing within that time.

TENTATIVE SPECIFICATIONS

FOR

ZINC-COATED (GALVANIZED) IRON OR STEEL SHEETS[1]

A.S.T.M. Designation: A 93 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover sheets zinc-coated (galvanized) by the hot-dip process. The weight of the coating may be ordered if desired. When the coating weight is ordered, it shall be in accordance with the requirements prescribed in the first column of Table I. These specifications do not cover tests of commercial coatings for general utility or lighter coatings for reduction of liability of flaking in fabrication of sheets.

NOTE.—These specifications cover zinc-coated (galvanized) sheets for general use. It may be that a series of specifications each covering galvanized sheets for a specific purpose would be more useful. The committee desires particularly to obtain comments on this point.

Interpretation of Numerical Requirements

2. The numerical requirements of these specifications are subject to the interpretations set forth in the Proposed Recommended Practices for Designation of Numerical Requirements in Standards of the American Society for Testing Materials.[2] Particular attention is called to the use of the phrase "to the nearest . . . " in expressing specified limits.

Base Metal Manufacture

3. The base metal for the sheets shall be made by the acid-bessemer or basic-open-hearth process.

Base Metal Chemical Composition

4. No requirements for chemical composition of the base metal are specified, except that when a copper content is ordered it shall conform to the following requirements:

Copper, min., per cent (to the nearest 0.01 per cent)	Ladle analysis	0.20
	Check analysis	0.18

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 – 27) 1936 Book of A.S.T.M. Standards, Part I, p. 387.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 527 (1936).

Base Metal Check Analysis

5. A check analysis may be made by the purchaser, using drillings or millings from the test specimens specified in Section 9. The copper content thus determined shall conform to the requirements specified in Section 4.

Weight of Coating

6. (*a*) The weight of coating shall conform to the requirements specified in Table I for the ordered coating. The weight of coating is the total amount on both sides of a sheet, expressed in ounces per square foot of sheet.

(*b*) The sheet test shall be made on a lot of from one to ten sheets. The test lot shall be weighed to the nearest 0.05 oz. per sq. ft. of sheet of the ordered size of the test lot after pickling, washing, and drying; and again after coating; and the weight of coating shall be calculated to the nearest 0.05 oz. per sq. ft. of sheet of the ordered size.

(*c*) The triple-spot test shall consist of the average of determinations from the three specimens cut from the test sheet as provided in Section 9.

(*d*) The minimum-spot test shall be that one of the three specimens of the triple-spot test bearing the lightest coating, or the purchaser may select a single specimen taken from any part of the test sheet, no part of the specimen closer than 2 in. from the sides and 4 in. from the ends.

TABLE I.—ORDERED COATING AND MINIMUM COATING TEST LIMITS, OUNCES PER SQUARE FOOT.

Ordered Coating Weights and Minimum Coating Limits	Minimum Coating, by Sheet Test	Minimum Coating by Diagonal Triple-Spot Test	Minimum Coating by Single-Spot Test	Practicable Limits, Galvanized Sheet Gage
2.75	2.50	2.35	2.00	Nos. 8 to 24
2.50	2.25	2.10	1.80	Nos. 8 to 26
2.25	2.00	1.85	1.60	Nos. 8 to 28
2.00	1.75	1.65	1.40	Nos. 11 to 28
1.75	1.50	1.40	1.20	Nos. 14 to 28
1.50	1.25	1.15	1.00	Nos. 16 to 30
1.25	1.00	0.90	0.80	Nos. 18 to 30

(*e*) The weight of coating by the triple-spot and the minimum-spot tests shall be determined to the nearest 0.01 oz. per sq. ft. by the hydrochloric acid - antimony chloride, the sulfuric acid, or other method as described in the Standard Methods of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A.S.T.M. Designation: A 90) of the American Society for Testing Materials.[1] The weight of coating in grams on a square sample 2.254 in. on a side or a circular sample 2.543 in. in diameter is numerically equal to the weight of coating in ounces per square foot of sheet.

Base Metal Bend Tests

7. The bend test specimen specified in Section 9 shall stand being bent cold through 180 deg. flat on itself without fracture of the base metal.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 397.

Coating Bend Tests

8. The bend test specimen specified in Section 9 shall stand being bent cold through 180 deg. without flaking of the coating on the specimen. The number of pieces of the same gage as the test specimen by which the inside of the bend is spaced shall be as shown in Table II. A vise with smooth jaws and operated by hand shall be used for making the bend tests. Flaking of coating within $\frac{1}{4}$ in. of the edge of the test specimen shall be disregarded. Bend tests shall not be required of sheets ordered extra smooth or stretcher leveled.

Test Specimens

9. (*a*) For the triple-spot test three specimens[1] 2.250 ± 0.005 in. square or 2.540 ± 0.005 in. in diameter shall be cut from each test sheet, one being cut from the center and the others from diagonally opposite corners, adjacent to, and within the boundary formed by lines 2 in. from the sides and 4 in. from the ends.

TABLE II.—COATING BEND TESTS.

NOTE.—Spacing of the inside of the bend determines the severity of the test and is specified in this table by the number of pieces, of the same gage as tested, used to space the bend. For weights of coating and gages for which no figures are given it is impracticable to make a coating bend test.

Ordered Coating, oz. per sq. ft.	Number of Pieces of Same Gage Used in Coating Bend Tests							
	Galvanized Sheet Gage							
	No. 16	No. 18	No 20	No. 22	No. 24	No. 26	No. 28	No. 30
2.00	..	..	..	8	8	9	9	..
1.75	7	7	7	8	8	9	9	..
1.50	5	6	6	6	6	6	6	6
1.25	4	4	5	6	6	6	6	6

(*b*) The bend test specimens, 3 to 4 in. in width, shall be cut from the test sheet, within the boundary formed by lines 2 in. from the sides and 4 in. from the ends.

(*c*) Test specimens, so far as practicable, shall be cut from sheets that are imperfect in areas other than those from which the specimens are selected.

Number of Tests

10. (*a*) The sheet test shall be made on as nearly 1 per cent as practicable, of the sheets of each gage and ordered coating, at approximately hourly intervals.

(*b*) If any sheet-test lot fails to meet the requirement, two sheets coated at the same time shall be subjected to the triple-spot test, and if either of these sheets fails to meet the requirements, the last half of the number of sheets coated after the preceding weight test shall be rejected.

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[1] If desired, the three test specimens for the triple spot tests on sheets for culverts may be cut from either end of each test sheet, one being cut from the middle of the width of the sheet and the others from the sides and 4 in. from the ends.

(*c*) The bend and spot tests shall be made from one sheet in each lot of 1000 sheets, or fraction thereof, of each gage and ordered coating.

(*d*) If the sheet specified in Paragraph (*c*) fails to meet the bend or spot test requirements, retest shall be made from two other sheets in the same lot and if either of these sheets fails to meet the requirements, the lot shall be rejected.

Permissible Variations in Weight

11. Gage weights shall not vary from those in Table III by more than the limits shown in Table IV, calculated to the nearest fifth significant figure on the basis of the ordered size.

TABLE III.—GALVANIZED SHEET GAGE.

Galvanized Sheet Gage Number	Oz. per sq. ft.	Lb. per sq. ft.	Lb. per sq. in.	Galvanized Sheet Gage Number	Oz. per sq. ft.	Lb. per sq. ft.	Lb. per sq. in.
8.........	112.5	7.0312	0.048828	20..........	26.5	1.6562	0.011502
9.........	102.5	6.4062	0.044488	21..........	24.5	1.5312	0.010634
10.........	92.5	5.7812	0.040148	22..........	22.5	1.4062	0.0097656
11.........	82.5	5.1562	0.035807	23..........	20.5	1.2812	0.0088976
12.........	72.5	4.5312	0.031467	24..........	18.5	1.1562	0.0080295
13.........	62.5	3.9062	0.027127	25..........	16.5	1.0312	0.0071615
14.........	52.5	3.2812	0.022786	26..........	14.5	0.90625	0.0062934
15.........	47.5	2.9688	0.020616	27..........	13.5	0.84375	0.0058594
16.........	42.5	2.6562	0.018446	28..........	12.5	0.78125	0.0054253
17.........	38.5	2.4062	0.016710	29..........	11.5	0.71875	0.0049913
18.........	34.5	2.1562	0.014974	30..........	10.5	0.65625	0.0045573
19.........	30.5	1.9062	0.013238	31..........	9.5	0.59375	0.0041233
				32..........	9.0	0.56250	0.0039062

TABLE IV.—PERMISSIBLE VARIATIONS FROM ORDERED GAGE WEIGHT FOR ALL OF ONE GAGE AND SIZE.

Ordered Galvanized Sheet Gage	Variation from Gage Weight,[a] per cent		
	10 tons or over	Under 10 tons to 1 ton, inclusive	Under 1 ton
Nos. 8 to 16, inclusive.........	5.0	7.0	10.0
Nos. 17 to 22, inclusive.........	3.5	5.5	10.0
Nos. 23 to 32, inclusive.........	2.5	4.0	10.0

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[a] The tonnage ordered for shipment to one place at one time determines the permissible variation for that tonnage, though any partial shipment may have the greater permissible variation of its tonnage classification.

Permissible Variations in Dimensions, Sheets not Ordered Re-squared

12. (*a*) *Over-Width.*—Over-width (sheets not ordered re-squared) shall not exceed the permissible variations shown in the following table:

Ordered Width, in.	Ordered Length, in.	Permissible Variation Over Ordered Width, in. (to the nearest $\frac{1}{16}$ in.)
Up to 36, inclusive	Up to 120, inclusive..........................	$\frac{1}{4}$
Up to 36, inclusive	Over 120..................................	$\frac{5}{16}$
Over 36	Up to 120, inclusive..........................	$\frac{3}{8}$
Over 36	Over 120..................................	$\frac{7}{16}$

NOTE.—Sheets shall not be less than ordered width.

(*b*) *Over-Length.*—Over-length (sheets not ordered re-squared) shall not exceed the permissible variations shown in the following table:

ORDERED LENGTH, IN.	PERMISSIBLE VARIATION OVER ORDERED LENGTH, IN. (to the nearest $\frac{1}{8}$ in.)
96 or under	$\frac{3}{4}$
Over 96 up to 120, inclusive	1
Over 120 up to 144, inclusive	$1\frac{1}{4}$
Over 144 up to 168, inclusive	$1\frac{1}{2}$
Over 168	$1\frac{3}{4}$

NOTE.—Sheets shall not be less than ordered length.

(*c*) *Out-of-Square.*—Out-of-square (sheets not ordered re-squared) shall not be more than $\frac{1}{16}$ in. per 4 in., or fraction thereof, of ordered width, measured along an end edge. Out-of-square is the greatest deviation, to the nearest $\frac{1}{16}$ in., of an end edge from a straight line at right angle to a side and touching one corner.

(*d*) *Camber.*—Camber (sheets not ordered re-squared), the greatest deviation of a side edge from a straight line touching both ends of the side, shall not exceed the limits shown in the following table:

ORDERED LENGTH, IN.	CAMBER, IN. (to the nearest $\frac{1}{16}$ in.)
72 or under	$\frac{1}{4}$
Over 72 up to 96, inclusive	$\frac{3}{8}$
Over 96 up to 120, inclusive	$\frac{1}{2}$
Over 120 up to 144, inclusive	$\frac{5}{8}$
Over 144 up to 156, inclusive	$\frac{3}{4}$
Over 156 up to 168, inclusive	$\frac{7}{8}$
Over 168	1

Permissible Variations in Dimensions, Sheets Ordered Re-squared

13. When sheets are ordered re-squared, the width and length shall not be less than ordered; over-width, over-length, out-of-square and camber, measured to the nearest $\frac{1}{32}$ in., shall not be more than $\frac{1}{16}$ in. for sheets not over 48 in. in width or 120 in. in length; or $\frac{1}{8}$ in. for wider or longer sheets. When sheets are ordered re-squared before coating, double these variations shall be permissible.

Permissible Over-Size

14. Over-size, when sheets are ordered for reshearing by the purchaser, shall be $\frac{1}{8}$ in. for each additional intended cut in addition to the variations prescribed in Sections 12 and 13.

Finish

15. The sheets shall be of prime finish, that is, free from injurious defects, such as blisters, flux, and uncoated spots.

Marking

16. The top sheet of each bundle or the top sheet of a number of sheets when shipped loose, shall, unless otherwise ordered, show legibly the name and brand of the manufacturer, gage, size and ordered coating.

Inspection

17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

18. If the purchaser elects to test and inspect the material at its destination, sheets represented by specimens which fail to conform to the requirements of these specifications will be rejected and the manufacturer shall be notified within two weeks from receipt of shipment by the consignee.

Rehearing

19. Sheets and specimens tested in accordance with Section 18, which represent rejected material, shall be preserved for two weeks from the date of notification to the manufacturer. In case of dissatisfaction with the results of the test, the manufacturer may require a rehearing within that time.

TENTATIVE METHOD OF TEST

FOR

UNIFORMITY OF COATING BY THE COPPER SULFATE DIP TEST (PREECE TEST) ON ZINC-COATED (HOT-GALVANIZED) STEEL CASTINGS AND FORGINGS, GRAY-IRON AND MALLEABLE-IRON CASTINGS[1]

A.S.T.M. Designation: A 208 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method covers the procedure by which the Preece test shall be performed to determine the uniformity of the zinc coating (galvanizing) on steel castings and forgings, gray-iron and malleable-iron castings.

Nature of Test

2. This test is useful only for determining uniformity of the coating.[2]

Copper Sulfate Solution

3. (*a*) The copper sulfate solution shall be made by dissolving approximately 36 parts by weight of commercial copper sulfate crystals in 100 parts by weight of distilled water. Warm water may be used to hasten the solution of the copper sulfate crystals. The solution shall then be shaken or air agitated until a specific gravity in excess of 1.186 at 18 C. (65 F.) has been reached. It shall then be allowed to stand for 48 hr. after which the supernatant liquid shall be carefully removed to a clean glass container. About 0.529 oz. (15 g.) of copper oxide (Paragraph (*b*)) shall be added to each 5 gal. (18.9 liters) of solution and agitated (air may be used) for at least 3 hr. The final specific gravity shall be adjusted (Paragraph (*c*)) to 1.186 at 18 C. (65 F.). The solution shall not be used for at least 24 hr. A truly neutral solution of copper sulfate will have a pH value of about 3.3.

(*b*) Powered cupric hydroxide, $Cu(OH)_2$, may be used instead of copper oxide, CuO, as a neutralizer, in which case the neutralization time may be reduced to 1 hr.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

[2] For further information on this method of test, reference may be made to the following papers:
H. H. Walkup and E. C. Groesbeck ,"Some Factors Affecting the Preece Test for Zinc Coatings," *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part II, p. 456 (1932).
H. H. Walkup and E. C. Groesbeck, "Preece Test for Zinc Coating," National Bureau of Standards *Journal of Research*, Vol. 12, June, 1934, p. 785.

(*c*) The test solution shall have a specific gravity of 1.186 at 18 C. (65 F.). To adjust a solution of improper specific gravity: add distilled water when the specific gravity is high, and add a copper sulfate solution of a higher specific gravity when the test solution is low in gravity.

Conditions of the Test

4. (*a*) *Rinse Water.*—Ordinary clean tap water shall be used for rinsing the specimens after each copper sulfate dip. In the event of no available running water, the rinse water shall be changed after each dip. The temperature of the rinse water shall be from 15 to 21 C. (60 to 70 F.).

(*b*) *Quantity of Test Solution.*—The quantity of copper sulfate solution required for each test will depend on the superficial area of the test specimen and the weight of coating. It should not be less than 1.2 qt. (1135 ml.) per ounce of zinc coating on the specimen (Note 1) and shall be sufficient to cover the specimen so that the top of the solution is at least ½ in. above the top of the specimen. After completion of the test, the solution shall be discarded and a fresh solution used for any additional test. The test specimens shall not be allowed to touch each other or the sides of the container.

NOTE 1.—The theoretical minimum amount of copper sulfate solution required to dissolve 1 oz. of zinc is 0.4 qt. (378 ml.). The quantity specified (1.2 qt. per oz. of zinc coating) is three times this minimum to insure adequate rate of solution.

Hand-dipped malleable-iron castings having a section of approximately ⅜ in. will have a weight of coating varying from 3 to 6 oz. per sq. ft. and an average weight of coating of approximately 4 oz. per sq. ft.

(*c*) *Cleaning Specimens.*—The specimens shall be cleaned with carbon tetrachloride, gasoline or benzol, then rinsed with alcohol, and finally thoroughly washed with clean water and wiped dry with clean cotton cloth. Castings or shapes shall be brought to a temperature of from 60 to 70 F. (15 to 21 C.) prior to the beginning of the test.

Procedure

5. (*a*) The test specimens shall be immersed in the copper sulfate solution which shall be maintained at a temperature of between 16 to 20 C. (61 to 68 F.). The specimens, or specimen shall be allowed to remain in a fixed position in the solution for exactly 1 min. There shall be no agitation of the copper sulfate solution during the immersion period. After each dip the specimen shall be immediately washed in rinse water using a fiber bristle brush to remove any copper deposit that may have formed on the zinc coating. Before returning the specimens to the copper sulfate solution, they shall be well drained of excess rinse water, and preferably, wiped dry with a clean, dry cloth.

(*b*) Successive dips of 1 min. each shall be continued, with washing and wiping of the test specimen after each dip, until the specimens have withstood the required number of dips, or until the appearance of bright adherent copper having an area over 0.012 sq. in. (equivalent to circular area ⅛ in.

in diameter) indicates that the base metal beneath the coating has been exposed (Note 2). Should a small amount of copper be coated adherently to the zinc, it shall not be mistaken for the end point at which copper plates out onto the base metal (Note 3). All end points (appearance of bright adherent copper) shall be confirmed by a peeling test. A confirmation of an end point may be made at any time during or after a test by redipping the specimen in the copper sulfate solution, immediately withdrawing and washing it with a scrub brush in rinse water. A bright adhering copper deposit will be positive evidence that the end point had been reached on the previous dip. If the operator is able to peel the copper with an eraser or with the edge of a sharp tool and zinc appears underneath the copper, such appearances of deposited copper shall not be construed as an end point. The appearance of copper within 1 in. of a cut portion of a specimen shall likewise not be considered to be the end point of the test.

NOTE 2.—Experience has hown that a circular bare spot, not over $\frac{1}{8}$ in. in diameter, on a galvanized coating is protected against corrosion by the surrounding zinc when subjected to atmospheric exposure.

NOTE 3.—Cases may arise when, by reason of unusual surface conditions, the copper sulfate solution will not act normally on the zinc coating. For example, the solution may have no apparent attack on all or part of the surface, or false deposits of copper may appear on the zinc coating. In all such cases the test specimens shall be cleaned in alcohol, rinsed and wiped dry, and then immersed for 3 min. in a solution consisting of one part by volume of NH_4OH (sp. gr. 0.90) and nine parts of water, during which time the specimens may be scrubbed with cotton cloth; after cleaning, the specimens shall be washed and wiped dry. This cleaning method shall precede the testing by the copper sulfate method.

End Point

6. An end point shall be recognized by the appearance of bright, adherent copper of not less than 0.012 sq. in. in area (equivalent to circular area $\frac{1}{8}$ in. in diameter). A fine line appearance of copper on the top of screw threads, or on sharp edges of articles shall not be judged as an end point. Likewise, the failure of a coating at or adjacent to any cut or abrasion present on the original specimens shall not be considered as a failure.

TENTATIVE SPECIFICATIONS

FOR

ROLLED WROUGHT-IRON SHAPES AND BARS[1]

A.S.T.M. Designation: A 207 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. These specifications cover a general group of rolled wrought-iron structural shapes, sections and bars.

Manufacture

2. The shapes, sections, and bars shall be direct rolled or rolled from piles made from pig-puddled or processed wrought iron[2] and shall be free from any admixture of iron scrap or steel.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products which are free from foreign or bought scrap. Any local mill products used shall be the equal or of a higher grade than the material specified.

Chemical Composition

3. The iron shall conform to the following requirement as to chemical composition:

Manganese, max., per cent	0.06

Check Analysis

4. An analysis may be made by the purchaser from a broken tension test specimen representing each lot as specified in Section 8 (*a*). The chemical composition thus determined shall conform to the requirement specified in Section 3.

Tension Tests

5. (*a*) The iron shall conform to the following minimum requirements as to tensile properties:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

[2] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

	Round, Square and Hexagonal Bars under $1\frac{5}{8}$ in. in Diameter or Thickness	Round, Square and Hexagonal Bars over $1\frac{5}{8}$ in. and up to but not Including $2\frac{1}{2}$ in. in Diameter or Thickness	Round, Square and Hexagonal Bars $2\frac{1}{2}$ in. and over in Diameter or Thickness; All Flat Bars and Shapes
Tensile strength, min., lb. per sq. in.	48 000	47 000	46 000[a, b]
Yield point, min., lb. per sq. in....	0.60 tens. str.	0.55 tens. str.	0.50 tens. str.
Elongation in 8 in., min., per cent..	25	22	20
Reduction of area, min., per cent..	40	35	30[c]

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[a] When the sectional area exceeds 12 sq. in., the allowable minimum tensile strength shall be 45,000 lb. per sq. in.

[b] For sections less than $\frac{3}{16}$ in. in thickness, no tension tests will be required.

[c] For flat bars, shapes and sections less than $\frac{3}{8}$ in. in thickness, no reduction of area test will be required.

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine. The speed of the crosshead of the machine shall not exceed $\frac{3}{4}$ in. per min. before passing the yield point.

Bend Tests

6. (*a*) *Cold-Bend Tests.*—The test specimen shall stand being bent cold through 180 deg. around a pin, the diameter of which is equal to the thickness of the specimen, without fracture on the outside of the bend.

For sections less than $\frac{3}{16}$ in. in thickness, no bend test will be required.

(*b*) *Hot-Bend Tests.*—The test specimen, when heated to a temperature between 1700 and 1800 F. (925 to 980 C.) shall stand being bent through 180 deg. flat on itself without fracture on the outside of the bent portion.

(*c*) *Nick-Bend Tests.*—The specimen, when nicked 25 per cent around for round specimens and along one side for rectangular specimens to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen and broken slowly, shall show a wholly fibrous fracture.

(*d*) Bend tests may be made by pressure or by blows.

Test Specimens

7. Where practicable, tension and bend test specimens shall be the full section of material as rolled. Bars over 2 in. in diameter or thickness may be machined to a diameter of 1 in. for a length of at least 9 in. with enlarged ends. Test specimens for all structural shapes shall be machined from the rolled shapes into specimens of rectangular section. For flat bars the bend test specimen may be reduced to a width not less than the thickness of the bar; but in any case it is permissible to reduce the specimen to at least a one inch square. The edges of a machined specimen shall be rounded to a radius of $\frac{1}{16}$ in.

Number of Tests

8. (*a*) One test each of those noted in Sections 5 and 6 shall be made on representative samples from each lot of 100 shapes or bars. Where small lots of different sizes are to be tested, the material shall be grouped into lots of 5000 lb. or fraction thereof, without regard to size, and one test specimen representing each lot of 5000 lb. or fraction thereof shall be tested as specified in Sections 5 and 6.

(*b*) If any of the specimens originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen fails to meet the physical requirements of Section 5 and breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual specimen shall be rejected and one retest from a different bar will be allowed. If the retest also fails, the product represented by such test will be rejected.

Permissible Variations in Size and Weight

9. (*a*) Round, square, and hexagonal bars shall not vary more than the limits given in the following table:

NOMINAL SIZE, ROUND, SQUARE, AND HEXAGONAL BARS	PERMISSIBLE VARIATIONS IN SIZE, IN.	
	UNDER	OVER
Up to ½ in., inclusive	0.007	0.007
Over ½ in. up to 1 in., inclusive	0.010	0.010
Over 1 in. up to 2 in., inclusive	1/64	1/32
Over 2 in. up to 3 in., inclusive	1/32	3/64
Over 3 in. up to 5 in., inclusive	1/32	3/32
Over 5 in. up to 8 in., inclusive	1/16	1/8

(*b*) The width or thickness of flat bars shall not vary more than 2 per cent from that specified.

(*c*) *Shapes.*—The weights of each lot[1] of angles, tees, zees, channels, or other shapes in each shipment shall not vary from the weight ordered more than the amounts given in the following table:

SHAPES	THICKNESS, IN.	PERMISSIBLE VARIATIONS FROM NOMINAL WEIGHTS
Any dimension over 1½ in	Over 3/16	±4 per cent
All dimensions 1½ in. and less	Over 3/16	±5 per cent
Any dimension over 1½ in	3/16 and less	±6 per cent
All dimensions 1½ in. and less	3/16 and less	±7 per cent

Finish

10. The finished material shall be free from injurious defects and shall have a workmanlike finish.

Inspection

11. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the production of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the product is being furnished in accordance with these specifications. All tests and inspection (except check analyses) shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

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[1] The term "lot" here means all of the shape of each group dimension and group thickness shown in the table.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

12. Material which shows injurious defects during fabrication subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

13. Samples tested in accordance with Section 11 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

SPIEGELEISEN[1]

A.S.T.M. Designation: A 98 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover spiegeleisen in three grades, as follows:

Grade A,
Grade B, and
Grade C.

Basis of Purchase

2. The spiegeleisen shall be furnished in pigs or lumps and each shipment shall be uniform as to the grade specified.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

	Grade A	Grade B	Grade C
Manganese, per cent	16 to 19	19 to 21	25 to 28
Carbon, max., per cent	6.50	6.50	5.00
Phosphorus, max., per cent	0.25	0.15	0.15
Sulfur, max., per cent	0.05	0.04	0.04
Silicon	as specified	as specified	as specified

(*b*) The manufacturer shall furnish an analysis of each shipment showing the manganese content, and when required such of the other elements specified in Paragraph (*a*).

Packing

4. Spiegeleisen shall be packed in sound containers in such manner that none of the metal is lost in shipment.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the sampling, packing and shipping of material ordered. The manufacturer shall afford the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Spiegeleisen (A 98 – 27), 1936 Book of A.S.T.M. Standards, Part I, p. 503.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: A 103 – 36 T) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferromanganese described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS
FOR
FERROMANGANESE[1]

A.S.T.M. Designation: A 99 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover ferromanganese in six grades, as follows:

Standard ferromanganese	
Medium-carbon ferromanganese	Grade A Grade B Grade C
Low-carbon ferromanganese	Grade A Grade B

Basis of Purchase

2. Ferromanganese shall be furnished in pigs, or lumps, or crushed or screened to size, as specified.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

	Standard	Medium Carbon			Low Carbon	
		Grade A	Grade B	Grade C	Grade A	Grade B
Manganese, min., per cent	78.00	78.00	78.00	78.00	78.00	78.00
Carbon, max., per cent	7.50	1.50	1.50	1.50	as specified[a]	0.75
Silicon, max., per cent	1.00	1.00	1.50	2.50	1.00	7.00
Phosphorus, max., per cent	0.30	0.30	0.30	0.30	0.30	0.30
Sulfur, max., per cent	0.05	....	....	....	....	....

[a] Grade A, low-carbon ferromanganese may be obtained with the following maximum carbon contents: 0.75, 0.50, 0.30, 0.15, and 0.10.

(*b*) The manufacturer shall furnish an analysis of each shipment showing the manganese content, and when required such of the other elements specified in Paragraph (*a*).

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Ferromanganese (A 99 – 27), 1936 Book of A.S.T.M. Standards, Part I, p. 493.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Packing

4. Ferromanganese shall be packed in sound containers in such manner that none of the metal is lost in shipment.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the sampling, packing and shipping of material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: A 103 – 36 T) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferromanganese described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS
FOR
FERROSILICON[1]
A.S.T.M. Designation: A 100 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover ferrosilicon in six grades, as follows:

Grade A,
Grade B,
Grade C,
Grade D,
Grade E, and
Grade F.

Basis of Purchase

2. (*a*) The ferrosilicon shall be furnished in lumps, or crushed or screened to size, as specified.

(*b*) When furnished in lump or granulated form the ferrosilicon shall be free from excessive disintegration.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F
Silicon, per cent	90 to 95.00	80 to 90.00	72 to 79.00	47 to 52.00	25 to 30.00	14 to 18.00
Carbon, max., per cent	0.15	0.15	0.15	0.15	0.25	1.00
Sulfur, max., per cent	0.04	0.04	0.04	0.04	0.04	0.04
Phosphorus, max., per cent	0.05	0.05	0.05	0.05	0.06	0.08

(*b*) An analysis of each shipment of ferrosilicon shall be furnished the purchaser, showing the percentage of silicon.

Packing

4. Ferrosilicon shall be packed in sound containers in such manner that none of the metal is lost in shipment.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Ferrosilicon (A 100 - 27), 1936 Book of A.S.T.M. Standards, Part I, p. 498.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the sampling, packing and shipping of material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: A 103 - 36 T) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferrosilicon described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS

FOR

FERROCHROMIUM[1]

A.S.T.M. Designation: A 101 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover ferrochromium in four grades as follows:

High-carbon ferrochromium	Grade A
Low-carbon ferrochromium	Grade B Grade C Grade D

Basis of Purchase

2. (*a*) *High-Carbon Ferrochromium.*—Grade A material shall be furnished to size as specified.

(*b*) *Low-Carbon Ferrochromium.*—Material of Grades B, C and D shall be crushed to the specified size and mixed before packing, so that the quality in each package is uniform with the lot.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

	High Carbon	Low Carbon		
	Grade A	Grade B	Grade C	Grade D[a]
Chromium, per cent	60.00 to 75.00	65.00 to 75.00	65.00 to 75.00	65.00 to 75.00
Carbon, per cent	4.00 to 8.00	1.50 to 2.00	1.00 to 1.50	1.00 max.
Silicon, per cent	as specified	as specified	as specified	as specified

[a] Grade D material may be obtained with the following maximum carbon contents: 1.00, 0.50, 0.20, 0.15, 0.10, and 0.06.

(*b*) The manufacturer shall furnish an analysis of each shipment showing the chromium content, and when required such of the other elements specified in Paragraph (*a*).

Packing

4. Ferrochromium shall be packed in sound containers in such manner that none of the metal is lost in shipment.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Ferrochromium (A 101 - 27), 1936 Book of A.S.T.M. Standards, Part I, p. 492.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the sampling, packing and shipping of material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: A 103 - 36 T) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferrochromium described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS
FOR
FERROVANADIUM[1]

A.S.T.M. Designation: A 102 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.[2]

Scope

1. These specifications cover ferrovanadium in three grades as follows:

Grade A,
Grade B, and
Grade C.

Basis of Purchase

2. The material furnished under these specifications shall be crushed to the specified size, and mixed before packing, so that the quality in each package is uniform with the lot.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

	Grade A	Grade B	Grade C
Vanadium, per cent	30.00 to 40.00	35.00 to 45.00	35.00 to 45.00
Carbon, max., per cent	3.50	0.50	0.20
Silicon, max., per cent	13.00	3.50	1.25
Phosphorus, max., per cent	0.25	0.10	0.10
Sulfur, max., per cent	0.40	0.20	0.10
Aluminum, max., per cent	1.50	1.50	1.25

(*b*) The manufacturer shall furnish an analysis of each shipment showing the vanadium content, and when required such of the other elements specified in Paragraph (*a*).

Packing

4. Ferrovanadium shall be packed in sound containers in such manner that none of the metal is lost in shipment.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the sampling, pack-

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Ferrovanadium (A 102 – 27), 1936 Book of A.S.T.M. Standards, Part I, p. 501.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

ing and shipping of material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: A 103 – 36 T) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferrovanadium described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS

FOR

FERROMOLYBDENUM[1]

A.S.T.M. Designation: A 132 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover standard ferromolybdenum in two grades, as follows:

Grade A, and
Grade B.

Basis of Purchase

2. Unless otherwise specified, ferromolybdenum shall be furnished crushed to a size 1 in. or less.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

	GRADE A	GRADE B
Molybdenum, per cent	55.00 to 70.00	55.00 to 70.00
Carbon, max., per cent	0.25	2.50
Silicon, max., per cent	1.50	1.50
Sulfur, max., per cent	0.25	0.25
Phosphorus, max., per cent	0.10	0.10
Copper, max., per cent	1.00	1.00

(*b*) The manufacturer shall furnish an analysis of each shipment showing the molybdenum content, and when required such of the other elements specified in Paragraph (*a*).

Packing

4. Ferromolybdenum shall be packed in sound containers in such manner that none of the metal is lost in shipment.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the sampling, packing and shipping of material ordered. The manufacturer shall afford the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision and consolidation of, and are intended to supersede when adopted as standard, the present Standard Specifications for Ferromolybdenum (A 132 - 34) and for Low-Carbon Ferromolybdenum (A 145 - 34), 1936 Book of A.S.T.M. Standards, Part I, pp. 494, 496.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: **A 103 – 36 T**) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferromolybdenum described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS
FOR
FERROTUNGSTEN[1]

A.S.T.M. Designation: A 144 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover the standard grade of ferrotungsten only.

Basis of Purchase

2. Unless otherwise specified, ferrotungsten shall be furnished crushed to a size 1 in. and less.

Chemical Composition

3. (*a*) The material shall conform to the following requirements as to chemical composition:

Tungsten	70.00 to 80.00, as specified
Carbon, max., per cent	0.60
Phosphorus, max., per cent	0.05
Sulfur, max., per cent	0.06
Silicon, max., per cent	1.00
Manganese, max., per cent	0.75
Copper, max., per cent	0.10
Arsenic, max., per cent	0.10
Antimony, max., per cent	0.08
Tin., max., per cent	0.10
Sum of arsenic, antimony, and tin, max., per cent	0.20

(*b*) The manufacturer shall furnish an analysis of each shipment showing the tungsten content, and when required such of the other elements specified in Paragraph (*a*).

Packing

4. Ferrotungsten shall be packed in sound containers in such manner that none of the metal is lost in shipment.

Inspection

5. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Ferrotungsten (A 144 – 34), 1936 Book of A.S.T.M. Standards, Part I, p. 499.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

to all parts of the manufacturer's works which concern the sampling, packing and shipping of material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 per cent of the containers shall be sampled.

Rejection

6. Any claims or rejections based on check analysis shall be made within 30 days from receipt of material.

Sampling

7. The sampling shall be carried out in accordance with the Tentative Methods of Sampling Ferro-Alloys (A.S.T.M. Designation: A 103 – 36 T) of the American Society for Testing Materials.[1]

Chemical Analysis

8. The chemical analysis shall be carried out in accordance with the procedure for ferrotungsten described in the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 54 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE SPECIFICATIONS
FOR
MOLYBDENUM SALTS AND COMPOUNDS[1]

A.S.T.M. Designation: A 146 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover the standard grades of molybdenum salts and compounds.

Chemical Composition

2. (*a*) The material shall conform to the following requirements as to chemical composition:

Molybdenum, per cent	30.00 to 45.00
Sulfur, max., per cent	0.25
Phosphorus, max., per cent	0.10
Copper, max., per cent	1.00

(*b*) The manufacturer shall furnish an analysis of each shipment showing the molybdenum content, and when required such of the other elements specified in Paragraph (*a*).

Packing

3. Molybdenum salts shall be packed in bags containing 5 lb. of molybdenum content or in other sound containers in quantities as specified. The material furnished under these specifications shall be thoroughly mixed before packing so that the quality in each container is uniform with the lot.

Inspection and Rejection

4. If claim for rejection is to be made, the purchaser shall sample at least 10 per cent of the containers upon arrival of the material at its destination. Any claims or rejections shall be made within 30 days of receipt of the material.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

These specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Molybdenum Salts and Compounds (A 146 – 34), 1936 Book of A.S.T.M. Standards, Part I, p. 502.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Sampling

5. The material to be shipped in bags shall be sampled in accordance with the Tentative Method for Sampling Molybdenum Salts and Compounds for Metallurgical Use (A.S.T.M. Designation: A 156 - 34 T) of the American Society for Testing Materials[1] by the manufacturer at the time the material is being packed. The purchaser shall be privileged to have his representative present during such sampling at the manufacturer's works.

Chemical Analysis

6. The chemical analysis shall be carried out in accordance with the Tentative Methods of Chemical Analysis of Ferro-Alloys (A.S.T.M. Designation: E 31) of the American Society for Testing Materials.[2]

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 58 (1936).

[2] 1938 Supplement to A.S.T.M. Methods of Chemical Analyses of Metals, issued as a separate reprint.

TENTATIVE METHOD OF TEST
FOR
MEASURING INTERLAMINATION RESISTANCE OF STEEL[1]

A.S.T.M. Designation: A 34 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

1. This method provides a test for measuring the interlamination resistance of a structure composed of strips cut from electrical steel. The resistance is measured in the direction perpendicular to the plane of laminations and indicates the effectiveness of the sheet surface oxides or coatings in reducing intersheet losses.

Test Specimens

2. (*a*) The test specimen shall consist of strips weighing approximately 750 g., regardless of thickness, 25 cm. ($9\frac{27}{32}$ in.) in length, and 3 cm. ($1\frac{3}{16}$ in.) in width which shall be obtained from the Epstein core-loss test specimens. The strips shall be selected as representative of the surface condition of the steel (the direction of the grain is immaterial).

(*b*) The shearing burrs and loose particles shall be adequately removed.

Apparatus

3. (*a*) *Copper Plates.*—Two flat, smooth copper plates shall be provided, having minimum dimensions of 27 cm. ($10\frac{1}{16}$ in.) in length, 5 cm. ($1\frac{31}{32}$ in.) in width, and 0.4 cm. ($\frac{5}{32}$ in.) in thickness. To each plate shall be soldered or brazed two flexible copper cables not smaller in cross-sectional area than No. 10 B. & S. gage wire (5.26 sq. mm. or 0.00815 sq. in.). The lengths of the cables shall be governed by the arrangement of the test apparatus.

(*b*) *Insulating Blocks.*—Two insulating blocks shall be required. The length and width of the blocks shall be equal to or greater than the copper plates and the thickness shall be sufficient to withstand the specified pressure.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee A-6 on Magnetic Properties.

This method when adopted as standard is intended to be incorporated in the Standard Methods of Tets for Magnetic Properties of Iron and Steel (A.S.T.M. Designation: A 34 – 38), 1936 Book of A.S.T.M. Standards, Part I, p. 504.

(*c*) *Compression Machine.*—A compression testing machine, capable of exerting the specified pressure, shall be used.

(*d*) *Measuring Equipment.*—The resistance measuring equipment of the direct current type shall be used and shall be preferably one of the two following types:

(*1*) The Kelvin bridge or modification thereof, for the resistances ranging from 0.0001 to 10 ohms, and the Wheatstone bridge above 10 ohms, or

(*2*) A potentiometer for measuring direct current potentials from 0.1 mv. and over and a direct-current ammeter with a range of 0 to 5 amp.

(*e*) *Current.*—A suitable source of steady direct current shall be used such as a battery of ample capacity having a range of 1½ to 6 v., together with a variable resistor for current control having a minimum rating of 5 amp. (Voltages outside this range may be used by mutual agreement, between the manufacturer and the purchaser, if required by breakdown conditions.)

Test Procedure

4. (*a*) The test strips shall be stacked evenly, resting symmetrically on the bottom copper plate, which in turn shall be supported by one insulating block backed by a suitable foundation, all resting in the testing machine. A second copper plate shall be placed symmetrically on the test strips with the second insulating block backing the top copper plate, and being backed with suitable blocking, conducive to distributing the pressure uniformly through the strips.

(*b*) For either of the recommended test sets, one copper cable from each copper plate shall be used in the current circuit, and the remaining cable shall be used in the potential circuit.

(*c*) The recommended pressures for purpose of tests shall be 7.03, 14.06, 35.15, or 70.30 kg. per sq. cm. (100, 200, 500, or 1000 lb. per sq. in.); other pressures, depending upon the application, may be agreed upon by the manufacturer and the purchaser. If more than one test pressure is to be used, the pressures shall be applied in ascending order.

(*d*) At the agreed or specified pressures, the stack resistance shall be determined and converted into ohms per square centimeter per strip in accordance with the following formula:

$$R_S = \frac{AR}{S} = \frac{75\ R}{S}$$

where R_S = the average interlamination resistance factor in ohms per square centimeter per strip,

A = the strip area in square centimeters = 75,

R = the measured stack resistance in ohms, and

S = the number of strips.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-BASE ALLOYS IN INGOT FORM FOR PERMANENT MOLD CASTINGS[1]

A.S.T.M. Designation: B 112 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover commercial aluminum-base alloys in ingot form for remelting for the manufacture of permanent mold castings. The specific gravity of these alloys does not exceed 3.0. Thirteen alloys are specified and are designated Alloys 1, 1A, 2, 3, 4, 5, 6, 7, 8, 9, 9A, 10, and 11 (see Explanatory Note).

Process

2. The alloys may be made by any approved process.

Quality

3. The material covered by these specifications shall be of uniform quality and shall be free from dross, slag, and other harmful contamination.

Chemical Composition

4. The alloy shall conform to the chemical composition requirements specified in Table I.

Sampling for Chemical Analysis

5. (*a*) The sample for determining the chemical composition shall be taken by sawing, drilling, or milling the sample ingot in such a manner as to be representative of its average cross-section.

(*b*) The saw, drill, or cutter used for taking the sample shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

Methods of Chemical Analysis

6. The chemical analysis shall be made in accordance with the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (A.S.T.M. Designation: B 40 – 36 T) of the American Society for Testing Materials.[1]

Number of Tests

7. If the ingots are shipped in carload lots of the same alloy, not less than five ingots shall be taken at random from the carload for sampling.

TABLE I.—CHEMICAL COMPOSITIONS OF ALUMINUM-BASE ALLOY INGOTS FOR PERMANENT MOLD CASTINGS.

NOTE 1.—Where single limits are shown in this table these indicate the maximum amount permitted.

NOTE 2.—Analysis shall regularly be made only for the elements specifically mentioned in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified in the last column of the table.

NOTE 3.—The following applies to all specified limits in this table: For purposes of acceptance and rejection, an observed value or a calculated value obtained from analysis should be rounded off to the nearest unit in the last right-hand place of figures used in expressing the specified limit.

NOTE 4.—Titanium is permissible in Alloys 1A, 2, 3, 4, 5, 9, 9A, and 10, but the maximum shall not exceed 0.2 per cent.

Alloy	Aluminum, per cent	Copper, per cent	Iron, per cent	Silicon, per cent	Magnesium, per cent	Nickel, per cent	Zinc, per cent	Manganese, per cent	Total Other Impurities, max., per cent
1	remainder	4.5±0.4	0.8	2.5±0.4	0.2	....	0.2	0.3	0.3
1A	remainder	4.5±0.4	0.8	2.5±0.4	0.05	....	0.2	0.3	0.3
2	remainder	7.0±0.8	1.1	4.0	0.1	....	2.5	0.3	1.0[a]
3	remainder	4.5±0.4	0.8	5.5±0.5	0.1	....	0.5	0.3	0.5
4	remainder	$10.0^{+0.7}_{-0.5}$	1.3	0.8	$0.25^{+0.10}_{-0.05}$	0.3	0.4	0.25	0.3
5	remainder	10.1±0.6	1.0	4.0±0.5	$0.25^{+0.10}_{-0.05}$	....	0.5	0.3	0.5
6	remainder	1.0±0.4	1.1	12.0±0.8	1.1±0.15	2.5±0.4	0.1	0.05	0.2
7	remainder	1.5±0.4	0.7	12.3±0.6	0.6±0.1	0.05	0.4	0.75±0.15	0.3
8	remainder	0.2	0.6	11.0±0.8	0.05	....	0.3	0.5	0.5
9	remainder	0.3	0.6	$5.0^{+0.8}_{-0.3}$	0.05	....	0.3	0.3	0.3
9A	remainder	0.1	0.6	$5.0^{+0.8}_{-0.3}$	0.05	....	0.05	0.05	0.05 each
10	remainder	0.15	0.4	7.0±0.5	0.3±0.1	....	0.05	0.05	0.05 each
11	remainder	4.0±0.4	0.8	0.6	$1.5^{+0.3}_{-0.2}$	2.0±0.3	0.1	0.2	0.2

[a] Total of all elements other than aluminum not to exceed 14.0 per cent.

If the shipment is in less than carload lots, one sample ingot shall be taken for each 6000 lb. (2721.6 kg.) or fraction thereof. When it is deemed necessary, a sample may be taken from each melt of 500 lb. (226.8 kg.) or more of the alloy.

Inspection

8. (*a*) Inspection may be made at the manufacturer's works where the alloys are made, or at the point where they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 95 (1936).

Rejection

9. Material which does not conform to the requirements of these specifications may be rejected, and if rejected shall be replaced by the manufacturer without charge to the purchaser. The full weight of the rejected material shall be returned to the manufacturer.

Rehearing

10. In the case of dissatisfaction regarding rejections based on quality or chemical composition requirements as specified in Sections 3 and 4, respectively, the manufacturer may make claim for rehearing as a basis of arbitration within 15 calender days after receipt by the manufacturer of the rejection notification.

EXPLANATORY NOTE

NOTE.—Supplementary data pertaining to the alloys covered by these specifications when used in the form of permanent mold castings are given in the Tentative Specifications for Aluminum-Base Alloy Permanent Mold Castings (A.S.T.M. Designation: B 108 – 38 T) of the American Society for Testing Materials.[1]

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[1] See p. 636.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-BASE ALLOY PERMANENT MOLD CASTINGS[1]

A.S.T.M. Designation: B 108 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1936; REVISED, 1937, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover aluminum-base alloy permanent mold castings having a specific gravity of 3 or less. Eleven types of alloys are specified and are designated Alloys 1 to 11, inclusive. (See Table of Supplementary Data in the Appendix.)

2. These specifications refer to castings of two classes: namely,
Standard commercial quality for regular applications, and
Class A alloys where the greatest freedom from impurities is required for special applications.

Manufacture

3. The finished castings shall be uniform in composition and free from blow holes, cracks, shrinks, and other injurious defects.

Chemical Composition

4. The alloys shall conform to the chemical composition requirements specified in Table I.

Sampling for Chemical Analysis

5. (*a*) The samples for chemical analyses shall be selected as far as possible by heats or melts, or groups of heats or melts, unless otherwise mutually agreed upon by the manufacturer and the purchaser.

(*b*) The sample for determining the chemical composition shall be taken by sawing, drilling or milling the casting or test specimen in such a manner as to be representative of the material on test.

(*c*) The saw, drill, cutter, or other tool used for sampling the casting shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

Method of Chemical Analysis

6. The chemical analysis shall be made in accordance with the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (A.S.T.M. Designation: B 40 – 36 T) of the American Society for Testing Materials.[1]

Physical Properties

7. The physical properties as determined from test specimens shall conform to the requirements specified in Table II except as noted.

TABLE I.—CHEMICAL COMPOSITIONS OF ALUMINUM-BASE ALLOY PERMANENT MOLD CASTINGS.

NOTE 1.—Where single limits are shown these indicate the maximum amount permitted.

NOTE 2.—Analysis shall regularly be made only for the elements specifically mentioned in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of limits specified in the last column of the table.

NOTE 3.—The following applies to all specified limits in this table: For purposes of acceptance and rejection, an observed value or a calculated value obtained from analysis should be rounded off to the nearest unit in the last right-hand place of figures used in expressing the specified limit.

NOTE 4.—Titanium is permissible in Alloys 1A, 2, 3, 4, 5, 9, 9A, and 10, but the maximum shall not exceed 0.2 per cent.

Alloy	Aluminum, per cent	Copper, per cent	Iron, per cent	Silicon, per cent	Magnesium, per cent	Nickel, per cent	Zinc, per cent	Manganese, per cent	Total Other Impurities, max., per cent
1............	remainder	4.5±0.5	1.0	2.5±0.5	0.2	....	0.2	0.3	0.3
1A............	remainder	4.5±0.5	1.0	2.5±0.5	0.05	....	0.2	0.3	0.3
2............	remainder	7.0±1.0	1.4	4.0	0.1	....	2.5	0.3	1.0[a]
3............	remainder	4.5±0.5	1.0	5.5±0.5	0.1	....	0.5	0.3	0.5
4............	remainder	10.0±0.75	1.5	1.0	0.25±0.10	0.3	0.4	0.3	0.3
5............	remainder	10.0±1.0	1.2	4.0±0.5	0.25±0.10	....	0.5	0.3	0.5
6............	remainder	1.0±0.5	1.3	12.0±1.0	1.0±0.25	2.5±0.5	0.1	0.05	0.2
7............	remainder	1.5±0.5	0.9	12.25±0.75	0.55±0.15	0.05	0.4	0.75±0.15	0.3
8............	remainder	0.3	0.8	11.0±1.0	0.05	....	0.3	0.5	0.5
9............	remainder	0.4	0.8	$5.0\begin{cases}+1.0\\-0.5\end{cases}$	0.05	....	0.3	0.3	0.3
9A............	remainder	0.1	0.8	$5.0\begin{cases}+1.0\\-0.5\end{cases}$	0.05	....	0.05	0.05	0.05 each
10............	remainder	0.2	0.5	7.0±0.5	0.3±0.1	....	0.05	0.05	0.05 each
11............	remainder	4.0±0.5	1.0	0.7	1.5±0.3	2.0±0.3	0.1	0.3	0.3

[a] Total of all elements other than aluminum not to exceed 14.5 per cent.

Test Specimens

8. (*a*) The test specimens shall be separately cast in a permanent mold. The specimens shall have a gage section diameter of 0.505 in. ± 0.010 in., and a gage length of not less than 2¼ in. The radius of fillet shall be not less than ½ in. A larger radius is not objectionable. The gage section diameter may be slightly reduced in the middle to promote breaking in this area.

(*b*) If the castings are to be heat treated, the test specimens representing such castings shall be heat treated with the castings they represent. They shall not be machined prior to test except to adapt the grip ends of the specimen to the jaws of the testing machine in such a manner as to assure axial loading.

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 95 (1936).

Tension Tests

9. The tensile properties shall be determined in accordance with the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

Number of Tests

10. (*a*) The test specimens shall, so far as possible, be selected by heats or melts but, unless otherwise agreed upon by the purchaser or his representative and the manufacturer, two tension tests shall be made for each unit of 1000 lb. or fraction thereof, of clean castings.

TABLE II.—PHYSICAL PROPERTIES OF ALUMINUM-BASE ALLOY PERMANENT MOLD CASTINGS.

NOTE.—See Table of Supplementary Data in the Appendix.

ALLOY	CONDITION	TENSILE STRENGTH, MIN., LB. PER SQ. IN (TO THE NEAREST 1000 LB. PER SQ. IN.)	ELONGATION IN 2 IN., MIN., PER CENT (TO THE NEAREST 1 PER CENT)
1	Heat Treatment No. 1	33 000	4.5
	Heat Treatment No. 2	42 000	1[a]
1A	Heat Treatment No. 1	33 000	4.5
	Heat Treatment No. 2	42 000	1[a]
2	As-cast	23 000	....
3	As-cast	23 000	....
4	Heat Treatment No. 1	28 000	....
	Heat Treatment No. 2	38 000	....
5	As-cast	26 000	....
6	Heat Treatment No. 1	28 000	....
	Heat Treatment No. 2	36 000	....
7	Heat Treatment No. 1	32 000	....
	Heat Treatment No. 2	36 000	....
8	As-cast	27 000	3
9	As-cast	21 000	2
9A	As-cast	21 000	2.5
10	Heat Treatment No. 1	28 000	5
	Heat Treatment No. 2	30 000	3
11	Heat Treatment No. 1	33 000	....
	Heat Treatment No. 2	40 000	....

[a] For information only.

(*b*) If any test specimen shows defective machining or flaws, it may be discarded; in which case the purchaser or his representative and the manufacturer shall agree upon the selection of another specimen in its stead.

Retests

11. If the results of the tension tests do not conform to the tensile properties specified in Section 7, the castings may be reheat-treated but not more than twice. The results of acceptable tests shall conform to the tensile property requirements as specified in Section 7.

Inspection

12. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

(*b*) The general requirements specified in Section 3 shall be checked by visual inspection of the castings or by comparison with observational standards where such standards are established. It is advisable that observational standards representing acceptable material be set up which will govern when any question arises as to what defects are allowable under the best commercial practice.

(*c*) If the purchaser elects to have inspection made at the manufacturer's works, the manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

13. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected shall be replaced by the manufacturer without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

Rehearing

14. In the case of dissatisfaction regarding rejections based on chemical composition and tensile property requirements as specified in Sections 4 and 7, respectively, the manufacturer may make claim for a rehearing as a basis of arbitration within a reasonable time after receipt by the manufacturer of the rejection notification.

APPENDIX

The data in the following table are approximate and are supplied for general information only:

TABLE OF SUPPLEMENTARY DATA

Alloy	Approximate Specific Gravity	Corrosion Resistance	Casting Properties	Response to Heat Treatment	Principal Use	Machinability
1	2.76	Good	Good	Yes	General, where high strength and fair ductility are required	Excellent
1A	2.76	Good	Good	Yes	General, where high strength and high ductility are required.	Good
2	2.83	Fair	Good	Yes	General, automotive cylinder heads and washing machine agitators	Excellent
3	2.79	Fair	Excellent	No	General	Good
4	2.90	Fair	Good	Yes	Pistons and castings requiring high Brinell hardness	Excellent
5	2.88	Fair	Good	Yes	General	Good
6	2.68	Good	Fair	Yes	Pistons	Fair
7	2.67	Good	Fair	Yes	Pistons	Fair
8	2.64	Excellent	Excellent	No	General thin sections	Fair
9	2.66	Good	Good	No	General and cooking utensils	Fair
9A	2.66	Excellent	Good	No	General with maximum corrosion resistance.	Fair
10	2.65	Excellent	Excellent	Yes	General where high strength and corrosion resistance are required	Good
11	2.78	Good	Fair	Yes	Aircraft and Diesel engine pistons	Good

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM SHEET AND PLATE[1]

A.S.T.M. Designation: B 25 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1918; ADOPTED IN AMENDED FORM, 1929;
REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1936, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover aluminum sheet and plate. Commercial flat sheet shall be supplied on orders for sheet, except where coiled or strip sheet is specifically ordered.

Manufacture

2. The materials used for the production of aluminum sheet and plate shall be such as to produce products which comply with the physical and chemical properties prescribed in these specifications.

Chemical Composition

3. The sheet and plate shall conform to the following requirements as to chemical composition:

Iron plus silicon, max., per cent		1.0
Copper, max., per cent		0.2
Manganese, max., per cent		0.05
Other impurities	each, max., per cent	0.03
	total, max., per cent	0.10
Aluminum, per cent		remainder

NOTE.—Analysis shall regularly be made only for the elements mentioned in Section 3. If in the course of routine analysis, the presence of other elements is indicated, analysis shall be made to determine the amount of each which is present.

Samples

4. Samples for analysis shall be taken from a random sheet to represent each 1000 lb. (453.6 kg.) of sheet, and from a random plate to represent each 2000 lb. (907.2 kg.) of plate, or such other quantity as may be mutually agreed upon between the manufacturer and the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

These specifications are in effect a revision of and replace the former Standard Specifications for Aluminum Sheet (A.S.T.M. Designation: B 25 – 29) which were accordingly discontinued in 1933.

purchaser. Samples for analysis may be obtained from the tension or bend test specimens described in Section 7. The sample for analysis may be prepared by shearing or by drilling or machining without the use of any lubricant in such a manner as to give a sample representative of the entire cross-section of the sheet or plate. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser and one for an umpire if necessary.

Tensile Requirements

5. (*a*) Sheet shall be supplied in the temper specified in the contract or purchase order and shall conform to the following minimum requirements as to tensile properties for the specified temper and thickness:

TEMPER	THICKNESS, IN.	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., MINIMUM, PER CENT
Soft	0.013 to 0.019	15 500 max.	15
	0.020 to 0.031	15 500 max.	20
	0.032 to 0.050	15 500 max.	25
	0.051 to 0.249	15 500 max.	30
Half Hard	0.013 to 0.019	16 000 min.	3[a]
	0.020 to 0.031	16 000 min.	4[a]
	0.032 to 0.050	16 000 min.	5[a]
	0.051 to 0.113	16 000 min.	7[a]
	0.114 to 0.249	16 000 min.	7
Three-quarter Hard	0.013 to 0.019	19 000 min.	1
	0.020 to 0.031	19 000 min.	2
	0.032 to 0.050	19 000 min.	3
	0.051 to 0.162	19 000 min.	4
Hard	0.013 to 0.019	22 000 min.	1
	0.020 to 0.031	22 000 min.	2
	0.032 to 0.050	22 000 min.	3
	0.051 to 0.128	22 000 min.	4

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[a] This value is required for flat sheet. For coiled sheet in the half-hard temper, the elongation may be less than that for flat sheet by 1 per cent in 2 in. The maximum thickness of coiled or strip sheet commercially available in the half-hard temper is 0.080 in.

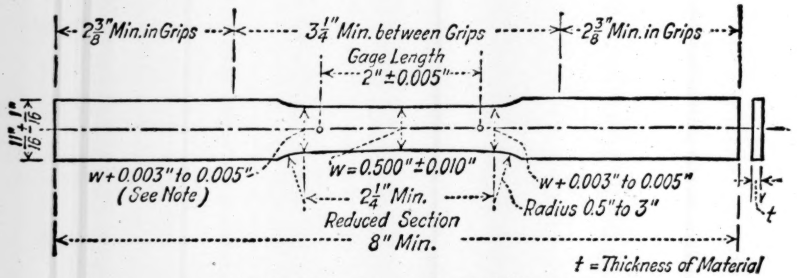
(*b*) Unless otherwise specified, plate (thicknesses 0.250 in. and over) shall be supplied as rolled. Mechanical property tests of as-rolled plate are not required except when specifically required by the order or contract. When so specified in the contract or order, plate shall conform to the following requirements:

THICKNESS, IN.	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
0.250 to 0.625	13 000	9
0.626 to 2.000	12 000	9
0.201 to 3.000	as agreed upon between the purchaser and the seller	...

(*c*) If so specified in the contract or order, plate shall be annealed. Annealed plate shall have a tensile strength not less than 11,000 lb. per sq. in. and not more than 15,500 lb. per sq. in., and the elongation in 2 in. shall not be less than 28 per cent.

Bend Tests

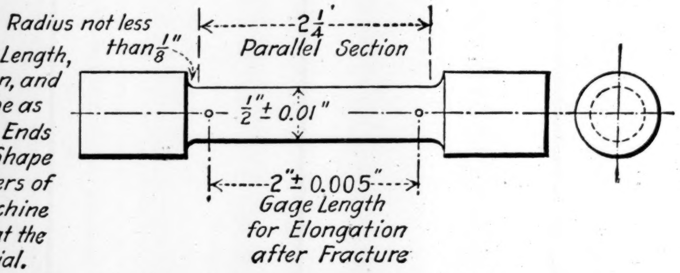
6. (*a*) Bend test specimens taken from sheet in the soft or in the half-hard temper or from plate in the soft temper or as rolled shall stand being bent cold through 180 deg. flat on themselves without cracking.


2 3/8" Min. in Grips
3 1/4" Min. between Grips
2 3/8" Min. in Grips
Gage Length
2" ± 0.005"
11/16" ± 1/16"
w + 0.003" to 0.005"
(See Note)
w = 0.500" ± 0.010"
2 1/4" Min.
Reduced Section
w + 0.003" to 0.005"
Radius 0.5" to 3"
8" Min.
t
t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.
All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet Metals.


Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Bend test specimens taken from sheet in the three-quarter-hard temper shall stand being bent cold through 180 deg. around a pin having a diameter equal to four times the thickness of the sheet without cracking.

(*c*) The bend test shall not be required for sheet in the hard temper.

Test Specimens

7. (*a*) *Tension Tests.*—Tension test specimens for sheet in the half-hard temper shall be taken parallel to the direction of rolling; for sheet in the soft, three-quarter-hard and hard tempers, the tension

test specimens may be taken in any direction. (See Explanatory Notes 1 and 3.) For sheet and plate under 0.500 in. in thickness the standard sheet tension test specimen shown in Fig. 1 shall be used. For plate 0.500 in. or over in thickness, the standard 0.505-in. diameter round specimen shown in Fig. 2 or a similar round specimen having the maximum possible dimensions proportional to those of the standard 0.505-in. diameter specimen shall be used.

(*b*) *Bend Tests.*—Bend test specimens may be taken in any direction from sheet in the soft, half-hard or three-quarter-hard temper and from plate in the soft temper or as rolled. Bend test specimens from thin sheet and strip shall be of the full thickness, and in the case of strips $\frac{3}{4}$ in. in width or under, of the full width of the material. The width of specimens from material over $\frac{3}{4}$ in. in width shall be six times the thickness, but not less than $\frac{3}{4}$ in. The edges may be rounded to a $\frac{1}{16}$-in. radius. When practicable the length shall be at least 6 in. For plates over 0.500 in. in thickness a machined bend test specimen $\frac{3}{4}$ by $\frac{1}{2}$ in. in cross-section and at least 6 in. in length shall be used. The edges may be rounded to a $\frac{1}{16}$-in. radius. When permitted by the inspector, the cross-section may be modified to $\frac{1}{2}$ in. square. In the case of plate $\frac{3}{4}$ in. or over in thickness, a $\frac{3}{4}$-in. round specimen machined from the material may be used. From plate $1\frac{1}{2}$ in. or over in thickness, the specimen shall be taken midway between the center and surface of the plate.

Number of Tests

8. One tension and one bend test specimen shall be taken from a random sheet to represent each 1000 lb. (453.6 kg.) of sheet, and from a random plate to represent each 2000 lb. (907.2 kg.) of plate, or such other quantity as may be agreed upon between the manufacturer and the purchaser.

Permissible Variations in Thickness

9. The thickness of flat sheet, coiled or strip sheet, and plate, shall not vary from that specified by more than the respective tolerances indicated in the following table:

FLAT SHEET

	18 IN. IN WIDTH AND UNDER	OVER 18 TO 36 IN., INCL., IN WIDTH	OVER 36 TO 54 IN., INCL., IN WIDTH	OVER 54 TO 72 IN., INCL., IN WIDTH	OVER 72 TO 90 IN., INCL., IN WIDTH	OVER 90 TO 102 IN., INCL., IN WIDTH
THICKNESS, IN.	THICKNESS TOLERANCE, PLUS OR MINUS, IN.					
0.249 to 0.129......	0.04T[a]	0.04T[a]	0.05T[a]	0.06T[a]	0.07T[a]	0.08T[a]
0.128 to 0.092......	0.004	0.0045	0.005	0.007	0.009	0.010
0.091 to 0.073......	0.003	0.003	0.004	0.006	0.008	......
0.072 to 0.051......	0.0025	0.003	0.004	0.005	0.007	......
0.050 to 0.037......	0.002	0.0025	0.003	0.004	......	......
0.036 to 0.018......	0.0015	0.002	0.0025	......	......	......
0.017 to 0.010......	0.0015	0.0015	0.002	......	......	......

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[a] T = the nominal thickness.

COILED SHEET

THICKNESS, IN.	12 IN. IN WIDTH AND UNDER	OVER 12 TO 24 IN., INCL., IN WIDTH	OVER 24 IN. IN WIDTH
	THICKNESS TOLERANCE, PLUS OR MINUS, IN.		
0.128 to 0.103	0.0035	0.0035	0.004
0.102 to 0.091	0.003	0.003	0.004
0.090 to 0.073	0.003	0.003	0.003
0.072 to 0.051	0.0025	0.003	0.003
0.050 to 0.041	0.0025	0.0025	0.0025
0.040 to 0.030	0.002	0.0025	0.0025
0.029 to 0.019	0.002	0.002	0.002
0.018 to 0.011	0.0015	0.002	......
0.010 to 0.008	0.001	0.0015	......
0.007 to 0.006	0.001	0.001	......

PLATE

THICKNESS, IN.	54 IN. IN WIDTH AND UNDER	OVER 54 TO 72 IN., INCL., IN WIDTH	OVER 72 TO 90 IN., INCL., IN WIDTH	OVER 90 TO 120 IN., INCL., IN WIDTH
	THICKNESS TOLERANCE, PLUS OR MINUS, PER CENT OF NOMINAL THICKNESS			
3.000 to 1.001	3	3	4	5
1.000 to 0.501	4	4	5	6
0.500 to 0.375	5	5	6	7
0.374 to 0.250	5	6	7	8

Workmanship and Finish

10. All sheet and plate shall be commercially flat and free from buckles; they shall be free from injurious surface defects and shall have a workmanlike finish. They shall be supplied to the dimensions specified within the limits of good commercial practice.

Inspection

11. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection

12. Materials which fail to conform to these specifications will be rejected and the manufacturer shall be notified. In case of rejection, the responsibility of the manufacturer shall be limited to replacing the material with other material which conforms to the requirements of these specifications, without charge to the purchaser.

EXPLANATORY NOTES

NOTE 1.—In the case of sheet in the half-hard temper, there is an appreciable difference in the elongation depending upon the direction in which the test specimen is taken from the sheet. This measurement made parallel to the direction of final rolling is distinctly higher than if the specimen were cut perpendicular to this direction. This difference is not observed in hard or soft sheet. The inspection of half-hard sheet calls for the use of specimens parallel to the direction of final rolling because of the greater contrast with the values obtained from hard sheet. The fact that the bend-test specimens may be taken without regard to the direction of rolling is evidence that the lower elongation across the grain does not indicate a lack of workability.

NOTE 2.—The mechanical properties of "as rolled" plate lie between those of the soft temper and those of the half-hard temper. Thinner plates (up to about 0.5 in.), because of the cooling during the rolling operation, have strengths which average around the minimum for half-hard temper. As the thickness increases the properties approach those of the soft temper. Where higher properties are required it is more economical to use a stronger aluminum alloy rather than to specify an intermediate temper (half-hard or quarter-hard) because of the cost of cold rolling heavy plates.

NOTE 3.—The use of grips which insure a uniform axial loading of the test specimen is essential, if satisfactory results are to be obtained.

A.S.M.E. BOILER CONSTRUCTION CODE
SPECIFICATION No.: S-39

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-MANGANESE ALLOY SHEET AND PLATE[1]

A.S.T.M. Designation: B 79 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1930; Adopted, 1931; Reissued as Tentative, 1933; Revised, 1934, 1936, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover aluminum-manganese alloy sheet and plate. Commercial flat sheet shall be supplied on orders for sheet, except where coiled or strip sheet is specifically ordered.

Manufacture

2. The materials used for the production of aluminum-manganese alloy sheet and plate shall be such as to produce products which comply with the physical and chemical properties prescribed in these specifications.

Chemical Composition

3. The sheet and plate shall conform to the following requirements as to chemical composition:

Manganese, per cent		1.0 to 1.5
Iron, max., per cent		0.7
Copper, max., per cent		0.2
Silicon, max., per cent		0.6
Other elements	each, max., per cent	0.03
	total, max., per cent	0.10
Aluminum, per cent		remainder

Note.—Analysis shall regularly be made only for the elements specified in Section 3. If in the course of routine analysis the presence of other elements is indicated, analysis shall be made to determine the amount of each which is present.

Samples

4. Samples for analysis shall be taken from a random sheet to represent each 1000 lb. (453.6 kg.) of sheet, and from a random plate to represent each 2000 lb. (907.2 kg.) of plate, or such other quantity as may be mutually agreed upon between the manufacturer and the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

These specifications are in effect a revision of and replace the former Standard Specifications for Aluminum-Manganese Alloy Sheet (A.S.T.M. Designation: B 79 – 31) which were accordingly discontinued in 1933.

purchaser. Samples for analysis may be obtained from the tension or bend test specimens described in Section 7. The sample for analysis may be prepared by shearing or by drilling or by machining without the use of any lubricant in such a manner as to give a sample representative of the entire cross-section of the sheet or plate. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser and one for an umpire if necessary.

Tensile Requirements

5. (*a*) Sheet shall be supplied in the temper specified in the contract or purchase order and shall conform to the following requirements as to tensile properties for the specified temper and thickness:

TEMPER	THICKNESS, IN.	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., MINIMUM, PER CENT
Soft	0.013 to 0.031	19 000 max.	20
	0.032 to 0.050	19 000 max.	23
	0.051 to 0.249	19 000 max.	25
Half hard	0.013 to 0.019	19 500 min.	3[a]
	0.020 to 0.031	19 500 min.	4[a]
	0.032 to 0.050	19 500 min.	5[a]
	0.051 to 0.113	19 500 min.	6[a]
	0.114 to 0.161	19 500 min.	7
	0.162 to 0.249	19 500 min.	8
Three-quarter hard	0.013 to 0.019	23 500 min.	1
	0.020 to 0.031	23 500 min.	2
	0.032 to 0.050	23 500 min.	3
	0.051 to 0.162	23 500 min.	4
Hard	0.013 to 0.019	27 000 min.	1
	0.020 to 0.031	27 000 min.	2
	0.032 to 0.050	27 000 min.	3
	0.051 to 0.128	27 000 min.	4

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[a] This value is required for flat sheet. For coiled sheet in the half-hard temper, the elongation may be less than that for flat sheet by 1 per cent in 2 in. The maximum thickness of coiled or strip sheet commercially available in the half-hard temper is 0.080 in.

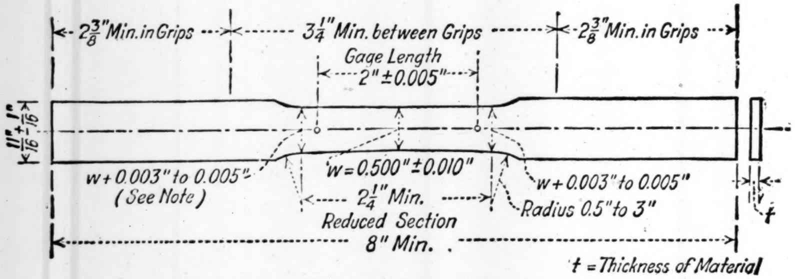
(*b*) Unless otherwise specified, plate (thicknesses 0.250 in. and over) shall be supplied as rolled. Mechanical property tests of as-rolled plate are not required except when specifically required by the order or contract. When so specified in the contract or order, plate shall conform to the following requirements:

THICKNESS, IN.	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
0.250 to 0.625	17 000	8
0.626 to 2.000	15 500	8
2.001 to 3.000	as agreed upon between the purchaser and seller.	..

(*c*) If so specified in the contract or order, plate shall be annealed. Annealed plate shall have a tensile strength not less than 14,000 lb. per sq. in. and not more than 21,000 lb. per sq. in., and the elongation shall not be less than 18 per cent in 2 in.

Bend Tests

6. (*a*) Bend test specimens taken from sheet in the soft temper and from annealed plate shall stand being bent cold through 180 deg. flat on themselves without cracking.

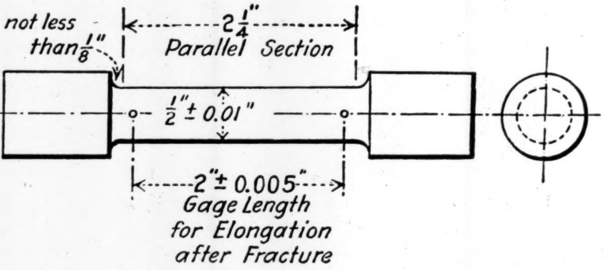

2 3/8" Min. in Grips
3 1/4" Min. between Grips
2 3/8" Min. in Grips
Gage Length
2" ± 0.005"
11/16" + 1/16"
w + 0.003" to 0.005"
(See Note)
w = 0.500" ± 0.010"
2 1/4" Min.
Reduced Section
w + 0.003" to 0.005"
Radius 0.5" to 3"
8" Min.
t
t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.

All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet Metals.


Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Bend test specimens taken from sheet in the half-hard temper in thicknesses up to $\frac{1}{8}$ in., inclusive, shall withstand being bent cold through 180 deg. flat on themselves. Bend test specimens taken from sheet thicker than $\frac{1}{8}$ in. in the half-hard temper, and from as-rolled plate shall stand being bent cold through 180 deg. around a pin having a diameter equal to two times the thickness of the specimen without cracking.

(*c*) Bend test specimens taken from sheet in the three-quarter-hard temper shall stand being bent cold through 180 deg. around a pin having a diameter equal to four times the thickness of the sheet without cracking.

(*d*) The bend test shall not be required for sheet in the hard temper.

Test Specimens

7. (*a*) *Tension Test Specimens.*—Tension test specimens for sheet in the half-hard temper shall be taken parallel to the direction of rolling; for sheet in the soft, three-quarter-hard and hard tempers the tension test specimens may be taken in any direction. (See Explanatory Notes 1 and 3.) For sheet and plate under 0.500 in. in thickness the standard sheet tension test specimen shown in Fig. 1 shall be used. For plate 0.500 in. or over in thickness, the standard 0.505-in. diameter round specimen shown in Fig. 2 or a similar round specimen having the maximum possible dimensions proportional to those of the standard 0.505-in. diameter specimen shall be used.

(*b*) *Bend Test Specimens.*—Bend test specimens may be taken in any direction from sheet in the soft, half-hard or three-quarter-hard temper and from plate in the soft temper or as rolled. Bend test specimens from thin sheet and strip shall be of the full thickness, and in the case of strips $\frac{3}{4}$ in. in width or under, of the full width of the material. The width of specimens from material over $\frac{3}{4}$ in. in width shall be six times the thickness, but not less than $\frac{3}{4}$ in. The edges may be rounded to a $\frac{1}{16}$-in. radius. When practicable the length shall be at least 6 in. For plates over 0.500 in. in thickness a machined bend test specimen $\frac{3}{4}$ by $\frac{1}{2}$ in. in cross-section and at least 6 in. in length shall be used. The edges may be rounded to a $\frac{1}{16}$-in. radius. When permitted by the inspector, the cross-section may be modified to $\frac{1}{2}$ in. square. In the case of plate $\frac{3}{4}$ in. or over in thickness, a $\frac{3}{4}$-in. round specimen machined from the material may be used. From plate $1\frac{1}{2}$ in. or over in thickness, the specimen shall be taken midway between the center and surface of the plate.

Number of Tests

8. One tension and one bend test specimen shall be taken from a random sheet to represent each 1000 lb. (453.6 kg.) of sheet, and from a random plate to represent each 2000 lb. (907.2 kg.) of plate, or such other quantity as may be mutually agreed upon between the manufacturer and the purchaser.

Thickness

9. The thickness of flat sheet, coiled or strip sheet, and plate, shall not deviate from that specified by more than the respective tolerances indicated in the following table:

Flat Sheet

	18 in. in Width and Under	Over 18 to 36 in., Incl., in Width	Over 36 to 54 in., Incl., in Width	Over 54 to 72 in., Incl., in Width	Over 72 to 90 in., Incl., in Width	Over 90 to 102 in., Incl., in Width
Thickness, in.	Thickness tolerance, plus or minus, in.					
0.249 to 0.129......	0.04T[a]	0.04T[a]	0.05T[a]	0.06T[a]	0.07T[a]	0.08T[a]
0.128 to 0.092......	0.004	0.0045	0.005	0.007	0.009	0.010
0.091 to 0.073......	0.003	0.003	0.004	0.006	0.008	......
0.072 to 0.051......	0.0025	0.003	0.004	0.005	0.007	......
0.050 to 0.037......	0.002	0.0025	0.003	0.004	......	......
0.036 to 0.018......	0.0015	0.002	0.0025	......	......	......
0.017 to 0.010......	0.0015	0.0015	0.002	......	......	......

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[a] T = the nominal thickness.

Coiled Sheet

	12 in. in Width and Under	Over 12 to 24 in., Incl., in Width	Over 24 in. in Width
Thickness, in.	Thickness tolerance, plus or minus, in.		
0.128 to 0.103....................	0.0035	0.0035	0.004
0.102 to 0.091....................	0.003	0.003	0.004
0.090 to 0.073....................	0.003	0.003	0.003
0.072 to 0.051....................	0.0025	0.003	0.003
0.050 to 0.041....................	0.0025	0.0025	0.0025
0.040 to 0.030....................	0.002	0.0025	0.0025
0.029 to 0.019....................	0.002	0.002	0.002
0.018 to 0.011....................	0.0015	0.002	......
0.010 to 0.008....................	0.001	0.0015	......
0.007 to 0.006....................	0.001	0.001	......

Plate

	54 in. in Width and Under	Over 54 to 72 in., Incl., in Width	Over 72 to 90 in., Incl., in Width	Over 90 to 120 in., Incl., in Width
Thickness, in.	Thickness tolerance, plus or minus, per cent of nominal thickness			
3.000 to 1.001....................	3	3	4	5
1.000 to 0.501....................	4	4	5	6
0.500 to 0.375....................	5	5	6	7
0.374 to 0.250....................	5	6	7	8

Workmanship and Finish

10. All sheet and plate shall be commercially flat and free from buckles; they shall be free from injurious surface defects and shall have a workmanlike finish. They shall be supplied to the dimensions specified within the limits of good commercial practice.

Inspection

11. The manufacturer shall afford the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection

12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified. In case of rejection, the responsibility of the manufacturer shall be limited to replacing the material with other material which conforms to the requirements of these specifications, without charge to the purchaser.

EXPLANATORY NOTES

NOTE 1.—In the case of sheet in the half-hard temper, there is an appreciable difference in the elongation depending upon the direction in which the test specimen is taken from the sheet. This measurement made parallel to the direction of final rolling is distinctly higher than if the specimen were cut perpendicular to this direction. This difference is not observed in hard or soft sheet. The inspection of half-hard sheet calls for the use of specimens parallel to the direction of final rolling because of the greater contrast with the values obtained from hard sheet. The fact that the bend test specimens may be taken without regard to the direction of rolling is evidence that the lower elongation across the grain does not indicate a lack of workability.

NOTE 2.—The mechanical properties of "as rolled" plate lie between those of the soft temper and those of the half-hard temper. Thinner plates (up to about 0.5 in.), because of the cooling during the rolling operation, have strengths which average around the minimum for half-hard temper. As the thickness increases the properties approach those of the soft temper. Where higher properties are required it is more economical to use a stronger aluminum alloy rather than to specify an intermediate temper (half-hard or quarter-hard) because of the cost of cold rolling heavy plates.

NOTE 3.—The use of grips which insure a uniform axial loading of the test specimen is essential, if satisfactory results are to be obtained.

TENTATIVE METHOD OF TEST
FOR
DIELECTRIC STRENGTH OF ANODIZED ALUMINUM[1]

A.S.T.M. Designation: B 110 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) This method is intended for determining the dielectric strength of anodic coatings applied to aluminum and its alloys.

(*b*) The dielectric strength of an oxide coating can be employed as an approximate measure of its thickness, provided the relation between thickness and dielectric strength has been determined for the specific type of coating under consideration.

NOTE.—The finish under test shall have a minimum break-down voltage of a value mutually agreed upon by the purchaser and the seller. Edges of holes and cut edges shall be exempt from the electrical break-down requirement, unless otherwise specified.

High-Voltage Transformer

2. (*a*) Any well-designed high-voltage transformer connected to an alternating current supply having as nearly a true sine wave as possible may be used. The transformer and source of supply of energy shall not be less than 2 kva. for voltages of 10,000 v. or less. The frequency shall not exceed 100 cycles per second.

(*b*) Regulation shall be so controlled that the high-tension testing voltage taken from the secondary of the testing transformer can be increased gradually from any point and in no case in increments of more than 25 v. Any method of regulating the voltage is satisfactory which does not distort the wave more than 10 per cent from a sinusoidal shape.

(*c*) The voltage may be measured by any approved method which gives root-mean-square values preferably by means of a voltmeter coil in the high-tension winding of the transformer or to a separate step-down instrument potential transformer. A voltmeter on the low-tension side of the transformer is satisfactory if the ratio of transformation does not change under any test condition.

(*d*) The apparatus used and the method of measuring the voltage shall meet the requirements of the Standards of the American Institute of Electrical Engineers.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

Electrode

3. (*a*) The electrode shall be made of brass, bronze, or copper, and shall have a smooth polished contact surface.

(*b*) For testing the finish, a conical electrode with a spherical apex of $\frac{1}{8}$-in. radius providing point contact with the surface of the coating shall be employed.

Test Specimens

4. The test specimens shall be representative of the coating to be tested, care being taken to selected samples which are free from abnormal defects.

Surrounding Medium

5. The tests shall be made in air with the specimen at room temperature.

Condition of Electrodes

6. The testing electrodes shall be kept clean and polished.

Position of Electrode on Specimen

7. The conical electrode shall be so designed and insulated that it can be conveniently moved from one position to another and supported during the operation of the test. Point contact shall be made with the electrode, and the potential applied through the film by flexible leads to the electrode and to the metallic under-surface. Contact with the under-surface shall be made by a slight scratch in the finish on an area which is not functionally involved in the performance of the part.

Application of Voltage

8. Starting at zero, the voltage shall be increased uniformly at the rate of 25 v. per sec. until break-down occurs.

Number of Tests

9. Unless otherwise specified, at least three tests shall be made and an average of these three puncturing voltages shall be taken. Where the size of the part warrants, a greater number of tests shall be made to obtain a reliable estimate of the general character of the finish.

TENTATIVE SPECIFICATIONS
FOR
MAGNESIUM-BASE ALLOY BARS, RODS AND SHAPES[1]

A.S.T.M. Designation: B 107 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1936; REVISED, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover commercial magnesium-base alloy extruded bars, rods, and shapes. Five alloys are specified and are designated Alloys Nos. 6, 8, 9, 11, and 15 (see Explanatory Note 1).

Manufacture

2. The alloys may be made from virgin metal or from purified scrap metal of known composition.

Chemical Composition

3. The bars, rods and shapes shall conform to the following requirements as to chemical composition:

Alloy	Magnesium per cent	Aluminum, per cent	Manganese, min., per cent	Zinc, per cent	Copper, max., per cent	Silicon, max., per cent	Other Impurities,[a] max., per cent
No. 6	remainder	3.3 to 4.7	0.20	0.3 max.	0.05	0.5	0.3
No. 8	remainder	5.8 to 7.2	0.15	0.4 to 1.0	0.05	0.5	0.3
No. 9	remainder	7.8 to 9.2	0.15	0.2 to 0.8	0.05	0.5	0.3
No. 11	remainder	....	1.20	....	0.05	0.3	0.3
No. 15	remainder	2.5 to 3.5	0.20	2.5 to 3.5	0.05	0.5	0.3

[a] Nickel, max., 0.03 per cent.

Sampling

4. The sample for chemical analysis may be taken by sawing, drilling, or milling and shall represent the average cross-section of the piece. The tool shall be thoroughly cleaned and no lubricant shall be used in the sampling operation. The sample shall weigh not less than 50 g.

Tension Tests

5. The material shall conform to the following requirements as to tensile properties:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

ALLOY	SHAPE AND SIZE	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	YIELD STRENGTH[a] (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN. MIN., PER CENT
No. 6	Round and Square up to 1½ in.	37 000	25 000	12
	Structural Shapes	34 000	17 000	10
No. 8	Round and Square up up to 1½ in.	40 000	26 000	12
	Structural Shapes	38 000	23 000	10
No. 9	Round and Square up to 1½ in.	43 000	28 000	9
	Structural Shapes	40 000	25 000	8
No. 11	Round and Square up to 1½ in.	32 000	20 000	3
No. 15	Round and Square up to 1½ in.	39 000	26 000	15
	Structural Shapes	39 000	22 000	10
No. 15A	Round and Square up to 1½ in.	41 000	30 000	10
	Structural Shapes	40 000	25 000	8

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[a] See Explanatory Note 2.

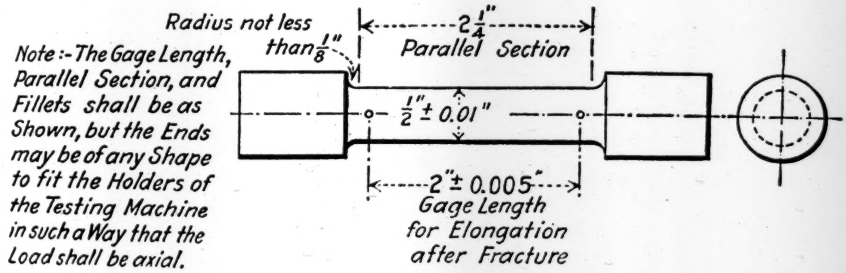

Radius not less than 1/8"
2 1/4"
Parallel Section
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Test Specimens

6. Tension test specimens shall be taken in such a manner that the longitudinal axis of the specimen is parallel to the direction of maximum flow of the metal. The specimen may be machined to the form and dimensions shown in Fig. 1, or in the case of thin material may be machined to the form and dimensions shown in Fig. 2, or may be the full section of the material.

Number of Tests

7. Two tension test specimens shall be taken to represent each 500 lb. or fraction thereof, or such other quantities as may be mutually agreed upon between the manufacturer and purchaser.

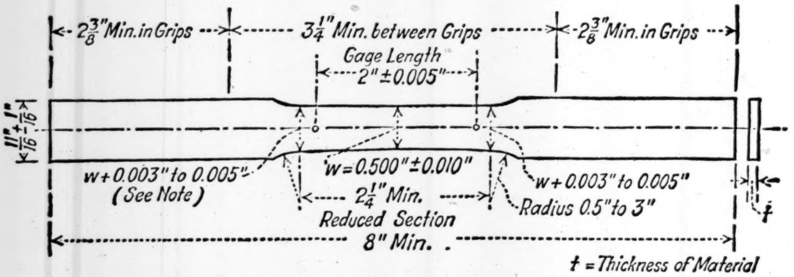
Permissible Variations in Dimensions

8. Variations from the specified dimensions shall not exceed the following:

MATERIAL	DIAMETER OR DISTANCE ACROSS FLATS	PERMISSIBLE VARIATIONS, IN., PLUS OR MINUS
Round, Square, Hexagonal, and Rectangular Bars	Up to 0.500	0.007
	0.501 to 1.000	0.010
	1.001 to 2.000	0.012
	2.001 to 3.000	0.015
	3.001 and over	0.018
Structural Shapes	Up to 0.125	0.010
	0.126 to 0.500	0.015
	0.501 to 1.000	0.020
	0.001 to 2.000	0.025
	2.001 to 3.000	0.030
	3.001 to 4.000	0.035
	4.001 to 5.000	0.045
	5.001 and over	0.060

Workmanship and Finish

9. All material shall be of uniform quality, free from injurious surface defects and shall have a workmanlike finish.



t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.

All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 2.—Standard Tension Test Specimen for Sheet Metals.

Inspection

10. (*a*) Inspection may be made at the manufacturer's works where the material is made, or at the point at which it is received, at the option of the purchaser.

(*b*) If the purchaser elects to have the inspection made at the manufacturer's works, the manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

11. Material which fails to meet these specifications may be rejected, and if rejected, the manufacturer's responsibility shall be limited to replacing the rejected material without charge to the purchaser. The full weight of the rejected material shall be returned to the manufacturer.

EXPLANATORY NOTES

NOTE 1: *Alloy No. 6.*—This alloy has a specific gravity of about 1.77. It has been the standard alloy used in the production of most extruded material. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 8.—This alloy has a specific gravity of about 1.80. It is superior to Alloy No. 6, both from the standpoint of mechanical properties and salt-water corrosion resistance and, hence, is rapidly replacing Alloy No. 6. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 9.—This alloy has a specific gravity of about 1.81. Its properties are superior to those of Alloys Nos. 6 and 8 but it is more difficult to fabricate and, hence, is used primarily in the production of special shapes requiring maximum properties. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 11.—This alloy has a specific gravity of about 1.76. It is recommended where maximum resistance to salt-water corrosion is required. Its properties are lower than those of the other magnesium alloys. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 15.—This alloy has a specific gravity of about 1.80. It possesses an excellent combination of high physical properties and good resistance to salt water. Its resistance to salt-water corrosion is superior to that of Alloys Nos. 6, 8, and 9 and in the aged condition (No. 15A) its yield strength is equal to that of any of the other alloys while it is easier to extrude than Alloy No. 9.

NOTE 2.—The yield strength of magnesium-base alloys is defined as the stress at which the stress-strain curve deviates 0.2 per cent from the modulus line. It may be determined by the "Offset Method" or the "Approximate Method Without the Stress-strain Diagram" (the latter is often referred to as the "Extension Under Load Method") as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

The following unit deformations for use with the "Approximate Method" are based on a modulus of elasticity, $E = 6{,}500{,}000$ lb. per sq. in.:

ALLOY	SHAPE AND SIZE	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	UNIT DEFORMATION, INCH PER INCH OF GAGE LENGTH
No. 6	Round and Square up to 1½ in.	25 000	0.0058
	Structural Shapes	17 000	0.0046
No. 8	Round and Square up to 1½ in.	26 000	0.0060
	Structural Shapes	23 000	0.0055
No. 9	Round and Square up to 1½ in.	28 000	0.0063
	Structural Shapes	25 000	0.0058
No. 11	Round and Square up to 1½ in.	23 000	0.0055
No. 15	Round and Square up to 1½ in.	26 000	0.0060
	Structural Shapes	22 000	0.0054
No. 15A	Round and Square up to 1½ in. (aged)	30 000	0.0066
	Structural Shapes (aged)	25 000	0.0058

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

TENTATIVE SPECIFICATIONS
FOR
MAGNESIUM-BASE ALLOY FORGINGS[1]

A.S.T.M. Designation: B 91 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1934, 1936, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover fully-worked (see Explanatory Note 1) commercial magnesium-base alloy forgings having a specific gravity of 1.9 or less. Six alloys are specified and are designated Alloys Nos. 1, 6, 8, 9, 15, and 16 (see Explanatory Note 2).

Manufacture

2. The alloys may be made from virgin metal or from purified scrap metal of known composition.

Chemical Composition

3. The forgings shall conform to the following requirements as to chemical composition:

Alloy	Magnesium, per cent	Aluminum, per cent	Manganese, min., per cent	Zinc, per cent	Copper, max., per cent	Tin, per cent	Silicon, max., per cent	Other Impurities,[a] max., per cent
No. 1.......	remainder	7.8 to 9.2	0.15	0.3 max.	0.05	....	0.5	0.3
No. 6.......	remainder	3.3 to 4.7	0.20	0.3 max.	0.05	....	0.5	0.3
No. 8.......	remainder	5.8 to 7.2	0.15	0.4 to 1.0	0.05	....	0.5	0.3
No. 9.......	remainder	7.8 to 9.2	0.15	0.2 to 0.8	0.05	....	0.5	0.3
No. 15.......	remainder	2.5 to 3.5	0.20	2.5 to 3.5	0.05	....	0.5	0.3
No. 16.......	remainder	3.0 to 4.0	0.20	0.3 max.	0.05	4.0 to 6.0	0.5	0.3

[a] Nickel, max., 0.03 per cent.

Sampling

4. The sample for chemical analysis may be taken by sawing, drilling, or milling and shall represent the average cross-section of the piece. The tool shall be thoroughly cleaned and no lubricant shall be used in the sampling operation. The sample shall weigh not less than 50 g.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

Tension Tests

5. The forgings shall conform to the following requirements as to tensile properties:

ALLOY	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	YIELD STRENGTH[a] (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
No. 1	42 000	24 000	5.0
No. 6	34 000	19 000	6.0
No. 8	38 000	22 000	6.0
No. 9	42 000	24 000	5.0
No. 15	38 000	20 000	9.0
No. 15A (aged)	38 000	22 000	7.0
No. 16	35 000	20 000	6.0

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[a] See Explanatory Note 3.

Test Specimens

6. Tension test specimens shall be taken in such a manner that the longitudinal axis of the specimen is parallel to the direction of the maximum flow of the metal in the forging and where practicable shall be taken from a full-size prolongation of the forging. The specimen may be machined to the form and dimensions shown in Fig. 1, or in the case of thin material may be machined to the form and dimensions shown in Fig. 2, or may be the full section of the material.

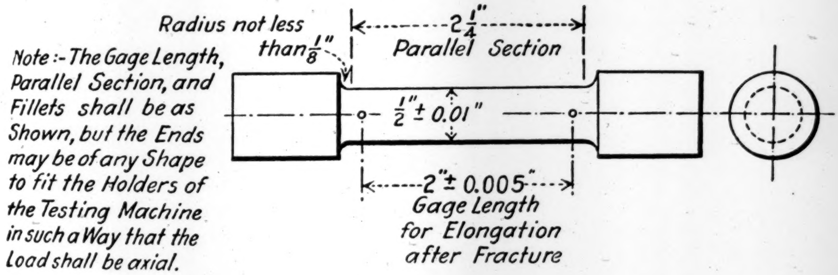

Radius not less than 1/8"
2 1/4"
Parallel Section
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Number of Tests

7. Two tension test specimens shall be taken to represent each 500 lb. or fraction thereof, or such other quantities as may be mutually agreed upon between the manufacturer and purchaser.

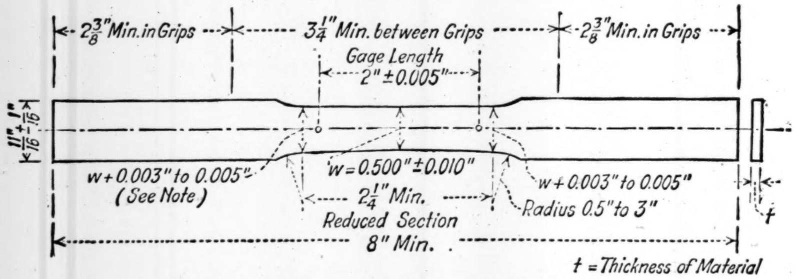
Workmanship and Finish

8. All material shall be of uniform quality, free from injurious surface defects and shall have a workmanlike finish.

Inspection

9. (*a*) Inspection may be made at the manufacturer's works where the material is made, or at the point at which it is received, at the option of the purchaser.

(*b*) If the purchaser elects to have the inspection made at the manufacturer's works, the manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.



Note: Gradual Taper from Ends of Reduced Section to Middle.
All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 2.—Standard Tension Test Specimen for Sheet Metals.

Rejection

10. Material which fails to meet these specifications may be rejected, and if rejected, the manufacturer's responsibility shall be limited to replacing the rejected material without charge to the purchaser. The full weight of the rejected material shall be returned to the manufacturer.

EXPLANATORY NOTES

NOTE 1.—The expression "fully worked" refers to material that has been worked sufficiently during the forging operations to develop maximum properties. Material that has been given smaller amounts of working will have correspondingly lower properties. Forging operations develop the maximum properties without the necessity of subsequent heat treatment.

NOTE 2. *Alloy No. 1.*—This alloy has a specific gravity of about 1.80. It can be readily fabricated under a press but cannot be hammer forged. It is stronger than Alloys Nos. 6 and 8 and has about the same mechanical properties as Alloy No. 9. It is sometimes used instead of Alloy No. 9 because it is less susceptible to cracking at elevated temperatures (hot shortness) during fabrication. Its resistance to corrosion is about the same as that of Alloy No. 9.

Alloy No. 6.—This alloy has a specific gravity of about 1.77. It is used for hot-press forgings and for hammer forgings of simple design. The forgeability of this alloy is superior to that of Alloys Nos. 8 and 9, but its physical properties average somewhat lower. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 8.—This alloy has a specific gravity of about 1.81. It is used for hot-press forgings. The properties of this alloy average somewhat higher than Alloy No. 6, and its resistance to salt-water corrosion is somewhat better than Alloys Nos. 6 and 9. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 9.—This alloy has a specific gravity of about 1.83. It is used for hot-press forgings of simple design requiring maximum properties. It has lower forgeability than the other alloys specified. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 15.—This alloy has a specific gravity of about 1.80. It has good press-forging characteristics and a greater resistance to salt water corrosion than Alloys Nos. 1, 6, 8, and 9. Forgings may be heat treated and aged to improve the yield strength. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 16.—This alloy has a specific gravity of about 1.87. It is the best alloy for hammer forging. Its physical properties are about the same as Alloy No. 6 but its salt-water corrosion-resistance and forging characteristics are distinctly better. The copper and nickel contents should be kept low to minimize corrosion.

NOTE 3.—The yield strength of magnesium-base alloys is defined as the stress at which the stress-strain curve deviates 0.2 per cent from the modulus line. It may be determined by the "Offset Method" or the "Approximate Method Without the Stress-strain Diagram" (the latter is often referred to as the "Extension Under Load Method") as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

The following unit deformations for use with the "Approximate Method" are based on a modulus of elasticity, $E = 6{,}500{,}000$ lb. per sq. in.:

ALLOY	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	UNIT DEFORMATION, INCH PER INCH OF GAGE LENGTH
No. 1	24 000	0.0057
No. 6	19 000	0.0049
No. 8	22 000	0.0054
No. 9	24 000	0.0057
No. 15	20 000	0.0051
No. 15A (aged)	22 000	0.0054
No. 16	20 000	0.0051

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

TENTATIVE SPECIFICATIONS

FOR

MAGNESIUM-BASE ALLOY INGOT FOR REMELTING[1]

A.S.T.M. Designation: B 93 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1936, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover commercial magnesium-base alloys in ingot form for remelting (Note 1). These alloys have a specific gravity of 1.9 or less. Thirteen alloys are specified and are designated Alloys Nos. 1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 14, 15, and 16 (Note 2).

NOTE 1.—Magnesium-base alloy ingots for remelting are normally furnished in the form of notched ingots 4 by 4½ by 26½ in. (4 notches) weighing approximately 18 lb., unless otherwise specified in the contract.

NOTE 2.—Explanatory Notes pertaining to the alloys covered by these specifications when used in the form of die castings, sand castings, sheet, and forgings are given in connection with the following tentative specifications of the American Society for Testing Materials: Tentative Specifications for Magnesium-Base Alloy Die Castings (A.S.T.M. Designation: B 94 – 37 T);[2] for Magnesium-Base Alloy Sand Castings (A.S.T.M. Designation: B 80 – 38 T);[3] for Magnesium-Base Alloy Sheet (A.S.T.M. Designation: B 90 – 38 T);[3] for Magnesium-Base Alloy Forgings (A.S.T.M. Designation: B 91 – 38 T);[3] and for Magnesium-Base Alloy Bars, Rods, and Shapes (A.S.T.M. Designation: B 107 – 38 T).[3]

Manufacture

2. (*a*) The alloys may be made from virgin metal or from purified scrap metal of known composition.

(*b*) The ingots shall be uniform in quality and shall be commercially free from slag or other foreign material.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 708 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 425.

[3] See pp. 664, 668, 658, 654.

Chemical Composition

3. The alloys shall conform to the following requirements as to chemical composition.

Alloy	Magnesium, per cent	Aluminum, per cent	Manganese, min., per cent	Zinc, per cent	Copper, max., per cent	Tin, per cent	Silicon, max., per cent	Other Impurities,[a] max., per cent
No. 1.......	remainder	8.0 to 9.0	0.18	....	0.04	....	0.2	0.3
No. 2.......	remainder	9.4 to 10.6	0.13	....	0.04	....	0.2	0.3
No. 3.......	remainder	11.5 to 12.5	0.13	....	0.04	....	0.2	0.3
No. 4.......	remainder	5.5 to 6.5	0.18	2.7 to 3.3	0.04	....	0.2	0.3
No. 6.......	remainder	3.5 to 4.5	0.25	....	0.04	....	0.2	0.3
No. 7.......	remainder	6.0 to 7.0	0.20	....	0.04	....	0.2	0.3
No. 8.......	remainder	6.0 to 7.0	0.20	0.4 to 1.0	0.04	....	0.2	0.3
No. 9.......	remainder	8.0 to 9.0	0.18	0.2 to 0.8	0.04	....	0.2	0.3
No. 11.......	remainder	....	1.30	....	0.04	....	0.1	0.2
No. 12.......	remainder	9.4 to 10.6	0.13	....	0.04	....	1.0	0.3
No. 14.......	remainder	9.4 to 10.6	0.13	0.7 to 1.3	0.04	....	0.2	0.3
No. 15.......	remainder	2.7 to 3.3	0.25	2.7 to 3.3	0.04	....	0.2	0.3
No. 16.......	remainder	3.2 to 3.8	0.25	....	0.04	4.3 to 5.7	0.2	0.3

[a] Nickel, max., 0.02 per cent.

Sampling

4. The sample for chemical analysis may be taken by sawing, drilling, or milling and shall represent the average cross-section of the ingot. The tool shall be thoroughly cleaned and no lubricant shall be used in the sampling operation. The sample shall weigh not less than 50 g.

Rejection

5. Material which fails to conform to the requirements of these specifications may be rejected, and if rejected, the manufacturer's responsibility shall be limited to replacing the rejected material without charge to the purchaser. The full weight of the rejected material shall be returned to the manufacturer.

TENTATIVE SPECIFICATIONS
FOR
MAGNESIUM-BASE ALLOY SAND CASTINGS[1]

A.S.T.M. Designation: B 80 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1930; Revised, 1931, 1934, 1936, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover commercial magnesium-base alloy sand castings having a specific gravity of 1.9 or less. Four alloys are specified and are designated Alloys Nos. 2, 3, 4, and 14 (see Explanatory Note 1).

Manufacture

2. (*a*) The alloys may be made from virgin metal or from purified scrap metal of known composition.

(*b*) Castings made from Alloys Nos. 2, 3, and 4 may be subjected to such heat treatment as the manufacturer desires to produce material that will conform to the requirements specified. Heat treatment shall be performed on the whole of a casting, never on a part only, and shall be applied in a manner that will produce the utmost uniformity.

Chemical Composition

3. The castings shall conform to the following requirements as to chemical composition:

Alloy	Magnesium, per cent	Aluminum, per cent	Manganese, min., per cent	Zinc, per cent	Copper, max., per cent	Silicon, max., per cent	Other Impurities,[a] max., per cent
No. 2	remainder	9.0 to 11.0	0.10	0.3 max.	0.05	0.5	0.3
No. 3	remainder	11.2 to 12.8	0.10	0.3 max.	0.05	0.5	0.3
No. 4	remainder	5.3 to 6.7	0.15	2.5 to 3.5	0.05	0.5	0.3
No. 14	remainder	9.0 to 11.0	0.10	0.5 to 1.5	0.05	0.5	0.3

[a] Nickel, max., 0.03 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

Sampling

4. The sample for chemical analysis may be taken by sawing, drilling, or milling the casting or tension test specimen and shall represent the average cross-section of the piece. The tool shall be thoroughly cleaned and no lubricant shall be used in the sampling operation. The sample shall weigh not less than 50 g.

Tension Tests

5. The tension test specimens representing the castings shall conform to the following requirements as to tensile properties:

ALLOY	CONDITION	TENSILE STRENGTH, MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
No. 2	Heat treated and aged	29 000	not required
No. 3	Heat treated and aged	27 000	not required
No. 4	As-cast	24 000	4
	Heat treated	30 000	6
	Heat treated and aged	32 000	2
No. 14	Heat treated and aged	30 000	not required

Test Specimens

6. The tension test specimens shall be separately cast in green sand and shall be "cast to size" according to the dimensions shown in Fig. 1. If the castings are heat treated, the tension test specimens representing such castings shall be similarly heat treated. They shall not be machined prior to test except to adapt the grips to the holders of the testing machine in such a manner as to insure an axial load.

Number of Tests

7. (*a*) The tests shall be made, so far as possible, by heats or melts, but unless otherwise mutually agreed upon by the manufacturer and purchaser, two tension tests shall be made for each unit of 500 lb. or fraction thereof.

(*b*) If any tension test specimen is improperly machined or shows flaws upon testing, it may be discarded; in which case the manufacturer and the purchaser, or his representative, may agree upon the selection of another specimen in its stead.

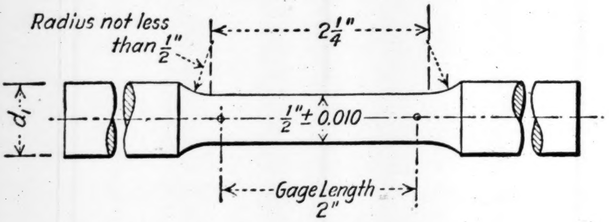
Workmanship and Finish

8. The castings shall be of uniform quality and condition, free from cracks or other injurious defects, and shall be well cleaned before inspection by sand-blasting or any other approved process.

Inspection

9. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have the inspection made at the manufacturer's works, the manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.



NOTE:

The Gage Length, Parallel Section and Fillets shall be as shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a way, that the Load shall be Axial.

In Order to promote the Breaking of the Specimen in the Center it is permissible to use a Taper in the Reduced Section from the Fillets to the Center of not to exceed 0.010 in.

It is recommended, that Diameter d_1 be from 3/4" to 1."

FIG. 1.—Tension Test Specimen.

Rejection

10. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected and, if rejected, the manufacturer's responsibility shall be limited to replacing the rejected material without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

EXPLANATORY NOTES

NOTE 1: *Alloy No. 2.*—This alloy has a specific gravity of about 1.81. It is used both in the solution heat-treated condition (H. T. No. 1) and in the solution heat-treated and aged conditions (H. T. No. 2 and H. T. No. 3). Aging increases the yield strength and hardness and decreases the toughness and elongation. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 3.—This alloy has a specific gravity of about 1.82. It is used in the solution heat-treated and aged condition (H. T. No. 3) for castings requiring the maximum obtainable yield strength. Toughness and elongation are low. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 4.—This alloy has a specific gravity of about 1.84. It is used in the as-cast, the solution heat-treated (H.T. No. 1), and the solution heat-treated and aged (H.T. No. 3) conditions. Its properties are somewhat better and its resistance to salt-water corrosion is decidedly better than in the case of Alloys Nos. 2 and 3, inclusive. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 14.—This alloy has a specific gravity of about 1.82. It is used in the solution-heat-treated and aged condition for castings requiring the maximum obtainable yield strength. Its physical properties are very similar to those of Alloy No. 3 but its salt-water corrosion-resistance and heat-treating characteristics are somewhat better. The copper and nickel contents should be kept low to minimize corrosion.

NOTE 2.—The yield strength of magnesium-base alloys is defined as the stress at which the stress-strain curve deviates 0.2 per cent from the modulus line. It may be determined by the "Offset Method" or the "Approximate Method Without the Stress-strain Diagram" (the latter is often referred to as the "Extension Under Load Method") as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

The following data give typical yield strength values for the various alloys, together with the corresponding unit deformations for use with the "Approximate Method" based on a modulus of elasticity, $E = 6,500,000$ lb. per sq. in.:

ALLOY	CONDITION	TYPICAL YIELD STRENGTH (OFFSET = 0.2 PER CENT), LB. PER SQ. IN.	UNIT DEFORMATION, IN. PER IN. OF GAGE LENGTH
No. 2	Heat treated and aged	19 000	0.0049
No. 3	Heat treated and aged	21 000	0.0052
No. 4	As-cast	11 000	0.0037
	Heat treated	11 000	0.0074
	Heat treated and aged	19 000	0.0098
No. 14	Heat treated and aged	22 000	0.0054

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

TENTATIVE SPECIFICATIONS
FOR
MAGNESIUM-BASE ALLOY SHEET[1]

A.S.T.M. Designation: B 90 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1934, 1936, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover commercial magnesium-base alloy sheet having a specific gravity of 1.8 or less. Three alloys are specified and are designated Alloys Nos. 6, 7, and 11 (see Explanatory Note 1).

Manufacture

2. The alloys may be made from virgin metal or from purified scrap metal of known composition.

Chemical Composition

3. The sheet shall conform to the following requirements as to chemical composition:

Alloy	Magnesium, per cent	Aluminum, per cent	Manganese, min., per cent	Copper, max., per cent	Zinc, max., per cent	Silicon, max., per cent	Other Impurities,[a] max., per cent
No. 6..........	remainder	3.3 to 4.7	0.20	0.05	0.3	0.5	0.3
No. 7..........	remainder	5.8 to 7.2	0.15	0.05	0.3	0.5	0.3
No. 11..........	remainder	....	1.20	0.05	....	0.3	0.3

[a] Nickel, max., 0.03 per cent.

Sampling

4. The sample for chemical analysis may be taken by sawing, shearing, or machining and shall represent the average cross-section of the sheet. The tool shall be thoroughly cleaned and no lubricant

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-7 on Light Metals and Alloys, Cast and Wrought.

shall be used in the sampling operation. The sample shall weigh not less than 50 g.

Tension Tests

5. The sheet shall conform to the following requirements as to tensile properties:

ALLOY	CONDITION	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD STRENGTH[a] (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	ELONGATION IN 2 IN., MIN., PER CENT
No. 6	Hard Rolled (H)	36 000 min.	25 000	4
	Annealed (A)	38 000 max.	......	10
No. 7	Hard rolled (H)	39 000 min.	28 000	3
	Annealed (A)	42 000 max.	.....	10
No. 11	Heat Treated (T)	35 000 max.	......	12
	Heat Treated and Rolled (TR)	32 000 min.	24 000	4

[a] See Explanatory Note 2.

Test Specimens

6. The tension test specimens may be cut in any direction irrespective of the direction of rolling and shall be machined to the form and dimensions shown in Fig. 1.

Number of Tests

7. Two tension test specimens shall be taken to represent each 500 lb. or fraction thereof, or such other quantities as may be mutually agreed upon between the manufacturer and purchaser.

Permissible Variations in Dimensions

8. *Thickness Tolerances.*—The thickness of sheets shall not vary from that specified by more than the following permissible variations:

	PERMISSIBLE VARIATIONS IN THICKNESS	
THICKNESS, IN.	SHEET UNDER 36 IN. IN WIDTH	SHEET 36 TO 50 IN. IN WIDTH
0.015 to 0.036	± 0.002 in.	± 0.0025 in.
0.037 to 0.050	± 0.0025 in.	± 0.003 in.
0.051 to 0.080	± 0.003 in.	± 0.004 in.
0.081 to 0.250	± 5 per cent of thickness	± 5 per cent of thickness

9. *Width Tolerances.*—The width of sheets shall not vary from that specified by more than the following permissible variations:

	PERMISSIBLE VARIATIONS IN WIDTH, IN.		
THICKNESS, IN.	SHEET 18 IN. AND UNDER IN WIDTH	SHEET OVER 18 TO 36 IN., INCL., IN WIDTH	SHEET 36 TO 50 IN. IN WIDTH
0.015 to 0.102	$\pm \frac{1}{16}$	$\pm \frac{3}{32}$	$\pm \frac{1}{8}$
0.103 to 0.250	$\pm \frac{3}{32}$	$\pm \frac{1}{8}$	$\pm \frac{3}{16}$

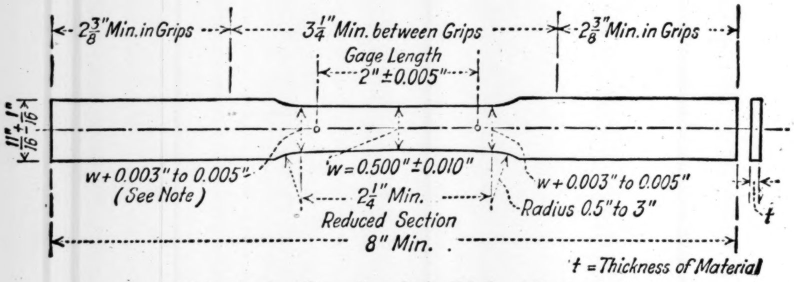
10. *Length Tolerances.*—(*a*) The length of sheets shall not vary from that specified by more than the following permissible variations:

	PERMISSIBLE VARIATIONS IN LENGTH, IN.			
THICKNESS, IN.	SHEET 18 IN. AND UNDER IN LENGTH	SHEET OVER 18 TO 48 IN., INCL., IN LENGTH	SHEET OVER 48 TO 120 IN., INCL., IN LENGTH	SHEET OVER 120 IN. IN LENGTH
0.015 to 0.250.....	$\pm \frac{1}{16}$	$\pm \frac{3}{32}$	$\pm \frac{1}{8}$	$\pm \frac{5}{32}$

(*b*) In case an exact length is specified, the permissible variation in length shall be $+\frac{1}{8}$ in. with no under tolerance.

Workmanship and Finish

11. All sheet shall be commercially flat and free from buckles, shall be free from injurious surface defects, and shall have a workmanlike finish.


$2\frac{3}{8}$" Min. in Grips
$3\frac{1}{4}$" Min. between Grips
$2\frac{3}{8}$" Min. in Grips
Gage Length
2" ± 0.005"
$\frac{11}{16}$" + $\frac{1}{16}$"
w + 0.003" to 0.005"
(See Note)
w = 0.500" ± 0.010"
w + 0.003" to 0.005"
$2\frac{1}{4}$" Min.
Reduced Section
Radius 0.5" to 3"
8" Min.
t
t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.

All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet Metals.

Inspection

12. (*a*) Inspection may be made at the manufacturer's works where the material is made, or at the point at which it is received, at the option of the purchaser.

(*b*) If the purchaser elects to have the inspection made at the manufacturer's works, the manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

13. Material which fails to meet these specifications may be rejected, and if rejected, the manufacturer's responsibility shall be limited to replacing the rejected material without charge to the purchaser. The full weight of the rejected material shall be returned to the manufacturer.

EXPLANATORY NOTES

NOTE 1. *Alloy No. 6.*—This alloy has a specific gravity of about 1.77. Its physical properties and forming characteristics are superior to those of Alloy No. 11. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 7.—This alloy has a specific gravity of about 1.79. Its physical properties are superior to Alloy No. 6 while its forming characteristics approach those of Alloy No. 6. The copper and nickel contents should be kept low to minimize corrosion.

Alloy No. 11.—This alloy has a specific gravity of about 1.76. It is recommended where maximum resistance to salt-water corrosion is required. The copper and nickel contents should be kept low to minimize corrosion.

NOTE 2.—The yield strength of magnesium-base alloys is defined as the stress at which the stress-strain curve deviates 0.2 per cent from the modulus line. It may be determined by the "Offset Method" or the "Approximate Method Without the Stress-strain Diagram" (the latter is often referred to as the "Extension Under Load Method") as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

The following unit deformations for use with the "Approximate Method" are based on a modulus of elasticity, $E = 6{,}500{,}000$ lb. per sq. in.:

ALLOY	YIELD STRENGTH (OFFSET = 0.2 PER CENT), MIN., LB. PER SQ. IN.	UNIT DEFORMATION, INCH PER INCH OF GAGE LENGTH
No. 6	25 000	0.0058
No. 7	28 000	0.0063
No. 11	24 000	0.0057

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

TENTATIVE SPECIFICATIONS

FOR

HARD-DRAWN COPPER ALLOY WIRES FOR ELECTRICAL CONDUCTORS[1]

A.S.T.M. Designation: B 105 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1936; REVISED, 1937, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover hard-drawn round copper alloy wires for electrical conductors.

Material

2. The material used shall be copper alloy of such nature and composition as to secure by proper treatment the qualities hereinafter specified for the finished wire. The copper used shall be electrolytic or low-resistance lake copper conforming in quality and purity to the requirements of either the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5)[2] or of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 4)[3] of the American Society for Testing Materials.

Grades

3. The copper alloy wires may be made in any one of ten distinct grades. The alloys have been designated as Grades Nos. 8.5 to 85, in accordance with their increasing conductivity, as follows:

Grade No. 8.5
Grade No. 13
Grade No. 15
Grade No. 20
Grade No. 30
Grade No. 40

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper and Copper Alloy Wires for Electrical Conductors.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 531.

[3] *Ibid.*, p. 526.

Grade No. 55
Grade No. 65
Grade No. 80
Grade No. 85

Chemical Composition

4. (*a*) The copper alloy wires shall conform to the following requirements as to chemical composition. The values given below embrace limits of composition of the different alloys which may be supplied (see Explanatory Note):

Silicon, max., per cent	3.00
Manganese, max., per cent	0.75
Tin, max., per cent	5.00
Aluminum, max., per cent	3.50
Cadmium, max., per cent	1.50
Iron, max., per cent	0.75
Copper, min., per cent	94.00
Sum of the above elements, min., per cent	99.50

(*b*) The maximum percentage of the various alloying elements to be found in any one of the ten grades is stated in the table in Paragraph (*a*). If the purchaser elects to check the composition of any material supplied to meet the performance requirements of any one of the above ten grades, the composition limits should be made the subject of a definite agreement between the manufacturer and purchaser in the placing of each individual order.

Chemical Analyses

5. Analyses may be made on each lot of 5000 lb. or fraction thereof. Millings or clippings shall be made from at least ten separate coils. Equal quantities shall be taken from each coil and shall be thoroughly mixed together. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

Joints

6. Welds and brazes may only be made in rods or in wires prior to final drawing.

Tensile Strength and Elongation

7. (*a*) The alloy wire of a designated grade shall be so drawn that its tensile strength and elongation shall be at least equal to the values given in Table I. Tension tests shall be made upon fair samples. The elongation of wire larger than 0.204 in. in diameter shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The elongation of wire 0.204 in. or smaller in diameter shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when

a load equal to 10 per cent of the specified tensile strength shall have been applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 60 in. as possible. The fracture shall be between the bench marks in the case of wire larger than 0.204 in. in diameter and between the jaws in the case of smaller wire, but not closer than 1 in. to either bench mark or jaw.

(*b*) If upon testing a sample from any coil of wire the results are found to be below the values stated in Table I, tests upon two additional samples shall be made and the average of the three tests shall determine the acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size given in Table I.

TABLE I.—MINIMUM REQUIREMENTS FOR TENSILE STRENGTH AND ELONGATION.

Diameter, in.	Area		Tensile Strength, min., lb. per sq. in.									Elongation, min., per cent	
	Circular mils	Square Inch	Grade No. 8.5	Grade No. 13	Grades Nos. 15 and 20	Grade No. 30	Grade No. 40	Grade No. 55	Grade No. 65	Grade No. 80	Grade No. 85	in 10 in.	in 60 in.
0 2893	83 690	0.06573....	97 500	102 500	109 500	74 000	73 400	76 000	67 500	72 000	68 500	2.17	....
0.2576	66 370	0.05213....	103 800	108 800	114 500	80 000	74 900	77 800	68 500	73 500	69 900	1.98	....
0.2294	52 640	0.04134....	107 500	112 500	118 500	85 000	76 300	79 300	69 400	75 000	71 200	1.79	....
0.2043	41 740	0.03278....	110 200	115 200	121 300	89 000	77 700	80 900	70 200	76 400	72 500	....	1.24
0.1819	33 100	0.02600....	112 200	117 200	123 300	92 500	79 000	82 400	71 000	77 500	73 600	....	1.18
0.1620	26 250	0.02062....	114 000	119 000	125 000	94 800	80 400	84 000	72 000	78 600	74 700	....	1.14
0.1443	20 820	0.01635....	115 300	120 300	126 500	96 500	81 800	85 500	72 900	79 800	75 800	....	1.09
0.1285	16 510	0.01297....	116 600	121 600	127 900	97 900	83 200	87 000	74 200	81 000	77 000	....	1.06
0.1144	13 090	0.01028....	117 800	122 800	129 200	99 000	84 600	88 500	74 500	82 200	78 100	....	1.02
0.1019	10 380	0.008155...	118 900	123 900	130 300	100 100	86 000	90 000	75 100	83 400	79 200	....	1.00
0.09074	8 234	0.006467...	119 800	124 800	131 200	101 200	87 100	91 300	75 600	84 600	80 300	....	0.97
0.08081	6 530	0.005129...	120 600	125 600	132 000	102 200	88 200	92 600	76 200	85 700	81 400	....	0.95
0.07196	5 178	0.004067...	121 200	126 200	132 600	103 000	89 600	93 800	76 800	86 800	82 500	....	0.92
0.06408	4 107	0.003225...	121 700	126 700	133 200	103 700	90 400	95 000	77 400	87 800	83 400	....	0.90
0.05707	3 257	0.002558...	122 200	127 200	133 600	104 400	91 400	96 000	77 700	88 700	84 200	....	0.89
0.05082	2 583	0.002028...	122 500	127 500	134 000	105 200	92 100	97 000	78 100	89 500	85 000	....	0.87
0.04526	2 048	0.001609...	122 800	127 800	134 250	105 900	93 100	98 000	78 600	90 300	85 700	....	0.86
0.04030	1 624	0.001276...	123 000	128 000	134 500	106 600	94 000	98 600	79 000	91 000	86 400	....	0.85
0.03589	1 288	0.001012...	123 200	128 200	134 750	107 300	94 500	99 000	79 300	91 600	87 000	....	0.84
0.03196	1 022	0.0008023..	123 500	128 500	135 000	108 000	95 000	99 500	79 600	92 200	87 600	....	0.82

(*c*) Tests upon a section of wire containing a drawn joint shall show at least 95 per cent of the tensile strength of the unjointed wire. Elongation tests are not to be made upon test sections including joints.

Resistivity

8. Electric resistivity shall be determined upon fair samples by resistance measurements. The resistivity at a temperature of 20 C. (68 F.) shall not be more than the values shown for the designated grade, as follows:

GRADE	MAXIMUM RESISTIVITY, POUNDS PER MILE OHM	MAXIMUM RESISTIVITY, OHMS PER CIRCULAR MIL FOOT
No. 8.5	10 169	122.00
No. 13	6 649	79.78
No. 15	5 605	69.14
No. 20	4 376	51.86
No. 30	2 917	34.57
No. 40	2 188	25.93
No. 55	1 591	18.86
No. 65	1 346	15.96
No. 80	1 094	12.96
No. 85	1 030	12.20

Permissible Variations in Diameter

9. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils.

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be as follows:

	OVER	UNDER
For wire 0.057 in. in diameter and larger..........	3 per cent	1 per cent
For wire less than 0.057 in. in diameter...........	1 mil	1 mil

(*c*) Each coil may be gaged at three places, one near each end and one approximately at the middle; the coil may be rejected if two points being within the accepted limits, the third point exceeds 4 per cent over, or 2 per cent under the nominal gage in the case of wire 0.057 in. in diameter or larger; or if the third point exceeds 1½ mils over or under the nominal gage in the case of wire less than 0.057 in. in diameter.

Density

10. For the purpose of calculating weights, cross-sections, etc., the density of the various alloys shall be taken as follows, based on a temperature of 20 C. (68 F.):

GRADE	DENSITY
Nos. 8.5 and 13..........................	8.78 g. per cu. cm., (0.3172 lb. per cu. in.)
No. 15..................................	8.54 g. per cu. cm., (0.3085 lb. per cu. in.)
Nos. 20, 30, 40, 55, 65, 80 and 85...........	8.89 g. per cu. cm., (0.3212 lb. per cu. in.)

Finish

11. The wire shall be free from all imperfections not consistent with the best commercial practice.

Packing and Shipping

12. (*a*) Package sizes for wire shall be agreed upon in the placing of individual orders.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

Inspection

13. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

EXPLANATORY NOTES

NOTE 1.—It is the intention of these specifications to permit under each of the ten grades listed in Section 3 any commercial alloy coming within the total range of analysis given in Section 4, provided the product complies with the other requirements of these specifications. For purposes of information only, the types of alloy now commonly used for each of the several grades are listed below. The chemical composition of any of the materials shall be within the total range required in Section 4, but in no case will the alloy contain the allowed maximum of more than one constituent other than copper.

GRADE	ALLOY TYPE
No. 8.5	Copper, Silicon, Iron Copper, Silicon, Manganese Copper, Silicon, Zinc Copper, Silicon, Tin, Iron Copper, Silicon, Tin, Zinc
No. 13	Copper, Tin, Aluminum Copper, Tin, Silicon Copper, Tin, Silicon, Aluminum
No. 15	Copper, Silicon, Aluminum Copper, Tin, Aluminum Copper, Tin, Aluminum, Silicon Copper, Tin, Silicon
No. 20	Copper, Tin
No. 30	Copper, Tin
No. 40	Copper, Tin Copper, Tin, Cadmium
No. 55	Copper, Tin, Cadmium
No. 65	Copper, Tin Copper, Tin, Cadmium
No. 80	Copper, Cadmium
No. 85	Copper, Cadmium

NOTE 2.—It is known that the rate of loading during tension testing of copper and copper alloys affects the performance of the sample to a greater or lesser extent, depending upon many factors. In general, tested values of tensile strength are increased and elongation values are reduced with increase of speed of the moving head of the testing machine. These effects are pronounced when the speed of the moving head is excessive in the tension testing of hard-drawn and medium-hard-drawn copper and copper-alloy wires. Pending the availability of more adequate information, it is suggested that tests on wire be made at speeds of moving head which under no-load conditions are not greater than 3 in. per min.

TENTATIVE SPECIFICATIONS
FOR
BARE, STRANDED COPPER CABLE: HARD, MEDIUM-HARD OR SOFT[1]

A.S.T.M. Designation: B 8 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) These specifications cover bare, stranded cables made from round copper wires, for general use as electrical conductors.

Classes

(*b*) For the purposes of these specifications, conductors are classified as follows (Notes 1 and 2):

Class AA.—For bare cable.

Class A.—For weather-resistant (weatherproof), slow-burning, slow-burning weather-resistant cables, and for bare cable where greater flexibility than is afforded by Class AA is required.

Class B.—For cable insulated with various materials such as rubber, paper, varnished cloth, etc., and for the cables indicated under Class A where greater flexibility is required.

Class C and Class D.—For cable where greater flexibility is required than is provided by Class *B* cable.

Requirements for Wires

2. (*a*) The purchaser shall designate the type of wire to be used in the cable.

(*b*) Before stranding, the copper wire used shall meet all of the requirements of the following standards of the American Society for Testing Materials, applicable to its class:

Standard Specifications for Soft or Annealed Copper Wire (A.S.T.M. Designation: B 3)[2]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper and Copper Alloy Wires for Electrical Conductors.

These specifications are in effect a tentative revision of and are intended to supersede when adopted as standard, the present Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard, or Soft (B 8 - 36), 1936 Book of A.S.T.M. Standards, p. 638; they also comprise a revision of the Tentative Specifications for Hard-Drawn Copper Transmission Cable (B 87 - 32 T), which were accordingly discontinued in 1938.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 665.

Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (A.S.T.M. Designation: B 33)[1]

Standard Specifications for Medium Hard-Drawn Copper Wire (A.S.T.M. Designation: B 2)[2]

Standard Specifications for Hard-Drawn Copper Wire (A.S.T.M Designation: B 1)[3]

(*c*) In concentric-lay cables the central core shall be made of wire of the same type and temper as the concentric layers, unless otherwise specified.

Joints

3. Welds and brazes may be made in rods or in wires prior to final drawing. Joints may not be made in the finished wires composing hard-drawn or medium hard-drawn Class *AA* cables of seven wires or less.

TABLE I.—MINIMUM DISTANCE BETWEEN JOINTS IN THE COMPLETED CABLE.

Number of Wires in Cable	Hard or Medium-Hard					Soft
	Class *AA*	Class *A*	Class *B*	Class *C*	Class *D*	All Classes
3	none permitted	....	....	....	....	1 ft.
7	none permitted	50 ft.	50 ft.	....	....	1 ft.
12	50 ft.	50 ft.	....	....	....	1 ft.
19	50 ft.	50 ft.	50 ft.	50 ft.	....	1 ft.
20 to 36	50 ft.	50 ft.	50 ft.	50 ft.	....	1 ft. in a layer[a]
37 to 60	25 ft.	25 ft.	25 ft.	25 ft.	25 ft.	1 ft. in a layer[a]
61 and over	.....	5 ft.	5 ft.	5 ft.	5 ft.	1 ft. in a layer[a]

[a] Except as indicated, the limitations apply to closeness of joints throughout the completed cable.

In other cables, welds and brazes may be made in the finished individual wires composing the cable, but shall not be closer together than as shown in Table I.

Lay

4. The lay or pitch of a layer of wires in concentric cable shall be not less than 10 nor more than 16 times the outside diameter of that layer, except that for cables composed of 37 wires or more, this requirement shall apply only to the two outer layers. The direction of lay of the outer layer shall be left-hand unless the direction of lay is specified otherwise by the purchaser. The direction of lay shall be reversed in successive layers unless specific instructions to the contrary are received from the purchaser.

Construction

5. The areas of cross-section, numbers and diameters of wires in the various classes of concentric-lay cables shall be as shown in Table II (Note 2).

Physical and Electrical Tests

6. (*a*) Tests for the physical and electrical properties of wires composing cables made from annealed copper wire or from tinned soft copper

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[1] 1936 Book of A.S.T.M. Standads, Part I, p. 669.

[2] *Ibid.*, p. 660.

[3] *Ibid.*, p. 655.

wire may be made before stranding or on wires removed from the cable. In the latter case the maximum tensile strength permitted shall be increased 5 per cent and the minimum elongation permitted shall be reduced 5 per cent (for example, from 30 per cent to 25 per cent). Care shall be taken to avoid mechanical injury of wire removed from cable for the purpose of testing.

TABLE II.—CONSTRUCTION REQUIREMENTS OF BARE CONCENTRIC-LAY COPPER CABLE.

Area of Cross-Section, circular mils	Size, American or B. & S. Wire Gage	Class *AA*		Class *A*		Class *B*		Class *C*		Class *D*	
		Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils
*5 000 000 .	....	....	....	169	172.0	217	151.8	271	135.8	271	135.8
4 500 000 .	....	....	....	169	163.2	217	144.0	271	128.9	271	128.9
4 000 000 .	....	....	....	169	153.8	217	135.8	271	121.5	271	121.5
3 500 000 .	....	....	....	127	166.0	169	143.8	217	127.0	271	113.6
*3 000 000 .	....	....	....	127	153.7	169	133.2	217	117.6	271	105.2
*2 500 000 .	....	....	....	91	165.7	127	140.3	169	121.6	217	107.3
*2 000 000 .	....	....	....	91	148.2	127	125.5	169	108.8	217	96.0
1 900 000 .	....	....	....	91	144.5	127	122.3	169	106.0	217	93.6
1 800 000 .	....	....	....	91	140.6	127	119.1	169	103.2	217	91.1
*1 750 000 .	....	....	....	91	138.7	127	117.4	169	101.8	217	89.8
1 700 000 .	....	....	....	91	136.7	127	115.7	169	100.3	217	88.6
1 600 000 .	....	....	....	91	132.6	127	112.2	169	97.3	217	85.9
*1 500 000 .	....	....	....	61	156.8	91	128.4	127	108.7	169	94.2
1 400 000 .	....	....	....	61	151.5	91	124.0	127	105.0	169	91.0
1 300 000 .	....	....	....	61	146.0	91	119.5	127	101.2	169	87.7
*1 250 000 .	....	....	....	61	143.1	91	117.2	127	99.2	169	86.0
1 200 000 .	....	....	....	61	140.3	91	114.8	127	97.2	169	84.3
1 100 000 .	....	....	....	61	134.3	91	109.9	127	93.1	169	80.7
*1 000 000 .	....	37	164.4	61	128.0	61	128.0	91	104.8	127	88.7
900 000 .	....	37	156.0	61	121.5	61	121.5	91	99.4	127	84.2
*800 000 .	....	37	147.0	61	114.5	61	114.5	91	93.8	127	79.4
*750 000 .	....	37	142.4	61	110.9	61	110.9	91	90.8	127	76.8
*700 000 .	....	37	137.5	61	107.1	61	107.1	91	87.7	127	74.2
650 000 .	....	37	132.5	61	103.2	61	103.2	91	84.5	127	71.5
*600 000 .	....	37	127.3	37	127.3	61	99.2	91	81.2	127	68.7
550 000 .	....	37	121.9	37	121.9	61	95.0	91	77.7	127	65.8
*500 000 .	....	19	162.2	37	116.2	37	116.2	61	90.5	91	74.1
450 000 .	....	19	153.9	37	110.3	37	110.3	61	85.9	91	70.3
*400 000 .	....	19	145.1	19	145.1	37	104.0	61	81.0	91	66.3
*350 000 .	....	12	170.7	19	135.7	37	97.3	61	75.7	91	62.0
*300 000 .	....	12	158.1	19	125.7	37	90.0	61	70.1	91	57.4
*250 000 .	....	12	144.3	19	114.7	37	82.2	61	64.0	91	52.4
*211 600	0000	7	173.9	12[a]	132.8	19	105.5	37	75.6	61	58.9
*167 800	000	7	154.8	12[a]	118.3	19	94.0	37	67.3	61	52.4
133 100	00	7	137.9	7	137.9	19	83.7	37	60.0	61	46.7
*105 500	0	7	122.8	7	122.8	19	74.5	37	53.4	61	41.6
*83 690 .	1	3	167.0	7	109.3	19	66.4	37	47.6	61	37.0
*66 370 .	2	3	148.7	7	97.4	7	97.4	19	59.1	37	42.4
*52 640 .	3	3	132.5	7	86.7	7	86.7	19	52.6	37	37.7
*41 740 .	4	3	118.0	7	77.2	7	77.2	19	46.9	37	33.6
*33 100 .	5	....	....	....	....	7	68.8	19	41.7	37	29.9
*26 250 .	6	....	....	....	....	7	61.2	19	37.2	37	26.6
*20 820 .	7	....	....	....	....	7	54.5	19	33.1	37	23.7
*16 510 .	8	....	....	....	....	7	48.6	19	29.5	37	21.1
*13 090 .	9	....	....	....	....	7	43.2	19	26.2	37	18.8
*10 380 .	10	....	....	....	....	7	38.5	19	23.4	37	16.7
*6 530 .	12	....	....	....	....	7	30.5	19	18.5	37	13.3
*4 107 .	14	....	....	....	....	7	24.2	19	14.7	37	10.5
*2 583 .	16	....	....	....	....	7	19.2	19	11.7	....	....
*1 624 .	18	....	....	....	....	7	15.2	19	9.2	....	....
*1 022 .	20	....	....	....	....	7	12.1	19	7.3	....	....

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* The sizes of cable which have been marked with an asterisk provide for one or more schedules of preferred series, and are commonly used in the industry. The sizes not marked are given simply as a matter of reference, and it is suggested that their use be discouraged.

[a] At present the prevailing practice in the industry is to supply 7-wire (Class *AA*) cables for gages Nos. 000 and 0000 weather-resisting (weatherproof) conductors, unless the application requires a more flexible stranding.

(*b*) If a tinning test is required, it shall be made on the wires prior to stranding.

(*c*) Tests for the physical and electrical properties of wires composing-cables made from hard-drawn or medium-drawn wire shall be made before but not after stranding.

(*d*) At the option of the purchaser, tension tests on hard-drawn and medium-hard-drawn wires before stranding may be waived, and completed hard-drawn and medium-hard-drawn cables may be tested as a unit. The tensile strength of bare cables so tested shall be at least 90 per cent of the total of the required minimum strengths of the component wires. The free length between grips of the test specimen shall be not less than 24 in., and care shall be taken to insure that the wires in the cable are evenly gripped during the test (Note 3).

(*e*) When requested by the purchaser at the time of placing the order, tension tests on hard-drawn and medium-hard-drawn wires before stranding or as a unit may be waived and tests made on wires removed from the completed cable. The test limits, based on a 10-in. gage length, for such tests shall be specified by the purchaser in the placing of individual orders (Note 4).

Weight and Resistance

7. (*a*) For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. (0.321 lb. per cu. in.) at 20 C. (68 F.).

(*b*) The electrical resistance and weight of a stranded conductor are greater than the total of these characteristics of the wires composing the cable, depending upon the lay or pitch. Two per cent shall be taken as the standard increment of increase of resistance and weight of concentric-lay cable, except that 1 per cent shall be taken as the standard increment for cable composed of three wires. In cases where the lay is definitely known, the increment shall be calculated and not assumed.

Variation in Area

8. The area of cross-section of the completed cable shall be not less than 98 per cent of the area specified. The area of cross-section of a cable shall be considered to be the sum of the cross-sectional areas of its component wires at any point when measured perpendicularly to their axes.

Packing and Shipping

9. (*a*) Package sizes for cable shall be agreed upon in the placing of individual orders (Notes 5 and 6). Unless otherwise agreed upon by the purchaser and the manufacturer, 90 per cent of the lengths as shipped on any one item shall be not less than 90 per cent nor more than 110 per cent of the length specified in the order. The remainder of the item may be shipped in random lengths of not less than 50 per cent of the specified length.

(*b*) The cable shall be protected against damage in ordinary handling and transportation.

(*c*) The net weight, length, size, kind of cable, purchase order number, and any other marks required by the purchase order shall be included on a tag attached to the end of the cable inside of the package. The same information together with the manufacturer's serial number and all shipping marks required by the purchaser shall appear on the outside of each package.

Inspection

10. All testing and inspection shall be made at the place of manufacture unless otherwise especially agreed upon between the manufacturer and the purchaser at the time of purchase. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

EXPLANATORY NOTES

NOTE 1.—In these specifications only concentric-lay cable constructions are specifically designated. Bunched-strands, rope-lay, or other cable constructions should be specifically agreed upon by the manufacturer and the purchaser when placing the order if other than concentric-lay cable is involved.

NOTE 2.—For definitions of terms relating to cable, reference should be made to the Definitions and General Standards for Wires and Cables (A.I.E.E. Standard No. 30-1932) approved by the American Standards Association (A.S.A. No. C8.1-1932).

NOTE 3.—To test cable for tensile strength successfully as a unit requires an adequate means of gripping the ends of the test specimen. Various means are available, such as a long tube or socket into which the cable may be soldered, or in which, after insertion, the cable may be swaged or pressed without serious distortion. Ordinary jaws or clamping devices usually are not suitable.

The cable testing facilities of many commercial laboratories are limited to a breaking strength of 30,000 lb. or less. Consequently, it is not feasible to test the very large sized cables as a unit. Where such is imperative, special arrangements for the testing shall be agreed upon between the manufacturer and the purchaser.

NOTE 4.—Wires unlaid from cable manifestly will have different physical and electrical properties from those of the wire when prepared for cabling, on account of the deformation brought about by laying and again straightening for test.

NOTE 5.—Because of the prohibition of joints in hard or medium-hard Class *AA* cables of 7 wires or less, it is necessary that the lengths of cable specified in the purchase order be such as practicably may be furnished by the manufacturer. In general, the maximum practicable length of such cable is determined by the weight of one of the component wires which can be placed on a spool or bobbin in the stranding machine. It is suggested that consideration be given to standardizing package lengths of Class *AA* cable as shown in Table III, which is based on a constant weight for the individual wires composing the cable.

NOTE 6.—It is of some importance that hard and medium-hard Class *AA* cable be placed on reels having drum diameters sufficiently large that the bending will not unduly modify the physical properties of the completed cable. It is suggested that consideration be given to standardizing on reel dimensions approximately as shown in Table III for such cable when ordered in the lengths shown. The drum diameters are not intended to indicate minimum desirable diameters for the associated cables, there being considerable leeway in this dimension for most cable sizes and constructions.

TABLE III.—SUGGESTED PACKAGE LENGTHS FOR HARD AND MEDIUM-HARD CLASS *AA* CABLE.[a, b]

Size of Cable, A.w.g. Numbers or Circular Mils	Number of Wires	Nominal Shipping Unit			Approximate Dimensions of Suitable Reel		
		Length, ft.	Cable Weight, lb.	Weight per Wire, lb.	Flange Diameter, in.	Traverse Width, in.	Drum Diameter, in.
No. 4	3	8400	1070	390	36	18	24
No. 3	3	6650	1070	390	36	18	24
No. 2	3	5300	1070	390	36	18	24
No. 1	3	4250	1070	390	36	18	24
No. 0	7	6250	2030	290	42	24	30
No. 00	7	4950	2030	290	42	24	30
No. 000	7	3900	2030	290	42	24	30
No. 000	12[b]	6700	3480	290	48	24	24
No. 0000	7	3100	2030	290	42	24	30
No. 0000	12[b]	5350	3480	290	48	24	24
250 000 cir. mils	12	4500	3480	290	48	24	24
250 000 cir. mils	19[b]	7150	5510	290	54	32	32
300 000 cir. mils	12	3750	3480	290	48	24	24
300 000 cir. mils	19[b]	5950	5510	290	54	32	32
350 000 cir. mils	12	3200	3480	290	48	24	24
350 000 cir. mils	19[b]	5100	5510	290	54	32	32
400 000 cir. mils	19	4450	5510	290	54	32	32
500 000 cir. mils	19	3550	5510	290	54	32	32

[a] These package lengths are based on cable furnished without joints or with a minimum of joints in the finished wires composing the completed cable.

[b] These optional constructions (Class *A*) are included as suggestions for use when the purchase order specifies Class *A* construction for bare hard or medium-hard cable.

Tentative Specifications for

ELECTROLYTIC CATHODE COPPER[1]

A.S.T.M. Designation: B 115 - 38 T

ISSUED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications apply to all electrolytic cathode copper.

Quality

2. (*a*) *Metal Content*.—The copper shall have a minimum purity of 99.90 per cent, silver being counted as copper.

(*b*) *Resistivity*.—The copper shall have a resistivity not to exceed 0.15436 international ohms per metergram at 20 C. (annealed). The resistivity shall be determined from a representative sample of each carload, or 50 tons, as a lot.

Chemical Analysis

3. Analysis for determining minimum purity shall be made in accordance with the Tentative Methods of Battery Assay of Copper (A.S.T.M. Designation: B 34) of the American Society for Testing Materials.[3]

Physical Condition

4. All cathodes shall be hard enough to stand ordinary handling without excessive breakage or excessive separation of nodules, and shall be substantially free from all foreign material, for example, copper sulfate, dirt, grease, and oil.

Claims

5. Claims shall be made in writing within two weeks of receipt of the copper by the purchaser, and the results of tests by the purchaser shall accompany such claims. The manufacturer shall be given one week from the date of receipt of the complaint to investigate his records, and shall either agree to replace the defective copper, or send a representative to the purchaser's mill. No claim shall be considered unless made as above stated, and if the copper in question, unused, cannot be shown to the representative of the manufacturer.

Claims against quality will be considered as follows:

(*a*) Metal content and resistivity by single carloads, or not exceeding 50-ton lots.

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[1] Under the standardization procedure of the Society these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

[3] A.S.T.M. Methods of Chemical Analyses of Metals, p. 111 (1936).

(*b*) Physical condition by individual pieces.

Investigation of Claims

6. (*a*) The representative of the manufacturer shall inspect all pieces where physical condition, or excessive foreign material is claimed. If agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

(*b*) In a question of metal content or resistivity, the cathodes in each lot to be investigated shall be sampled in the presence of both parties. As a sample, each party shall select one cathode or piece from every 10,000 lb., or fraction thereof, in the car or lot. The sample shall be drilled according to a template laid out to provide an even number of holes (with a minimum of four) approximately $\frac{1}{2}$ in. in diameter and equally spaced along a diagonal line projected between the opposite corners. No lubricant shall be used, and drilling shall not be forced sufficiently to cause oxidation of the chips. The resulting drillings shall be mixed and separated into four equal portions, each of which shall be placed in a sealed package, one for the purchaser, one for the manufacturer, the third for the umpire, if necessary, and the fourth as a reserve for contingencies.

(*c*) Each party shall make an analysis and resistivity determination and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final.

(*d*) In a question of resistivity, the sample shall be taken as described in Paragraph (*b*) and melted, under charcoal, in a pure graphite, carbon, or other non-contaminating crucible, cast into a suitable sample mold, and fabricated into a wire 0.080 in. in diameter, approximately, which shall be annealed at 500 C.

Settlement of Claims

7. The expenses of the manufacturer's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise. In case of rejection being established, the damage shall be limited to payment of freight both ways by the manufacturer and the substitution of an equivalent weight of copper meeting these specifications.

TENTATIVE SPECIFICATIONS

FOR

BRONZE CASTINGS FOR TURNTABLES AND MOVABLE BRIDGES AND FOR BEARING AND EXPANSION PLATES OF FIXED BRIDGES[1]

A.S.T.M. Designation: B 22 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1921; REISSUED IN AMENDED FORM AS TENTATIVE, 1936; REVISED, 1938.

Scope

1. (*a*) These specifications cover four classes of bronze castings for turntables and movable bridges and two classes of cast-bronze plates used in bridges and other structures for fixed and expansion bearings where motion is slow and intermittent.

(*b*) The purposes for which these classes are ordinarily used are as follows:

Class A.—For contact with hardened steel disks at low speeds under pressures not over 3000 lb. per sq. in., for example, disk-bearing metals used in center-bearing swing bridges.

Class B.—For contact with hardened steel disks at low speeds under pressures not over 2500 lb. per sq. in., for example, disk-bearing metals used in turntable and center-bearing swing bridges: for contact with steel (tensile strength 60,000 lb. per sq. in., min.) at low speeds under pressures not over 1500 lb. per sq. in., for example, trunnions of movable bridges; and for bearing and expansion plates under pressures not to exceed 2500 lb. per sq. in.

Class C.—For ordinary machinery bearings, and for bearing and expansion plates under pressures not to exceed 1000 lb. per sq. in.

Class D.—For gears, worm wheels, nuts and similar parts which are subjected to other than compressive stresses.

Manufacture

2. (*a*) The bronze shall be a homogeneous alloy of copper and tin.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

These tentative specifications are in effect a revision of, and replace the former Standard Specifications for Bronze Bearing Metals for Turntables and Movable Railroad Bridges (A.S.T.M. Designation: B 22 – 21), which standard was accordingly discontinued in 1936.

These specifications were prepared in cooperation with representatives of the American Association of State Highway Officials and the American Railway Engineering Association.

The copper shall conform to the requirements of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5),[1] or the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars, "high-resistance" grade (A.S.T.M. Designation: B 4),[2] of the American Society for Testing Materials. The bronze shall be made from new metal, except that scrap of known composition produced by the foundry at which the bronze is cast may be used.

(*b*) Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

Chemical Composition

3. The bronze shall conform to the following requirements as to chemical composition:[3]

ELEMENTS CONSIDERED	CLASS A	CLASS B	CLASS C	CLASS D
Copper, per cent	remainder	remainder	82 max.	89 max.
Tin, per cent	18 to 20	15 to 17	9 to 11	9 to 11
Lead, per cent	0.25 max.	0.25 max.	8 to 11	0.25 max.
Zinc, per cent	0.25 max.	0.25 max.	0.50 max.	1.75 to 2.25
Iron, max., per cent	0.25	0.25	0.25	0.25
Phosphorus, per cent	1.0 max.	1.0 max.	0.7 to 1.0	0.5 max.
Other impurities, max., per cent	0.5	0.5	0.5	0.5

Chemical Analyses

4. (*a*) An analysis of each melt may be made at the option of the purchaser. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.[3]

(*b*) The compression test coupon shall be used for analysis.

Methods of Analyses

5. Analyses, when made, shall be performed in accordance with the Tentative Methods of Chemical Analysis of Bronze Bearing Metal (A.S.T.M. Designation: B 46 - 36 T) of the American Society for Testing Materials.[4]

Compressive and Tensile Strengths

6. (*a*) The bronze shall conform to the following requirements as to compressive and tensile properties:

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 531.

[2] *Ibid.*, p. 526.

[3] Material with a range of composition differing from that specified in Section 3, or containing elements not specified, may be used, provided the manufacturer shall submit in writing previous to the execution of the contract the range of composition of the material he proposes to use, and provided this range of composition shall be accepted by the purchaser.

[4] A.S.T.M. Methods of Chemical Analyses of Metals, p. 157 (1936).

PROPERTIES CONSIDERED	CLASS A	CLASS B	CLASS C	CLASS D
COMPRESSION				
Deformation limit, min., lb. per sq. in.	24 000	18 000	....	....
Permanent set in 1 in. under 100 000 lb. per sq. in., in.	0.04 to 0.12	0.10 to 0.20	....	....
TENSION				
Tensile strength, min., lb. per sq. in.	....	....	....	33 000
Yield point, min., lb. per sq. in.	....	....	....	to be recorded
Elongation in 2 in., min., per cent	....	....	....	14

(*b*) The deformation limit in compression shall be determined as that load which produces a permanent set of 0.001 in. in the compression test specimen described in Section 6 (*b*).[1]

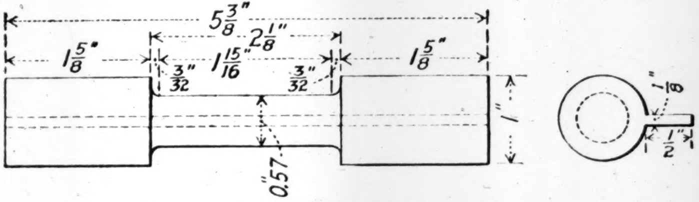
$5\frac{3}{8}"$
$2\frac{1}{8}"$
$1\frac{5}{8}"$
$\frac{3}{32}"$
$1\frac{15}{16}"$
$\frac{3}{32}"$
$1\frac{5}{8}"$
$1"$
$0.57"$
$\frac{1}{8}"$
$\frac{1}{2}"$

FIG. 1.—Test Bar for Tension Specimen.

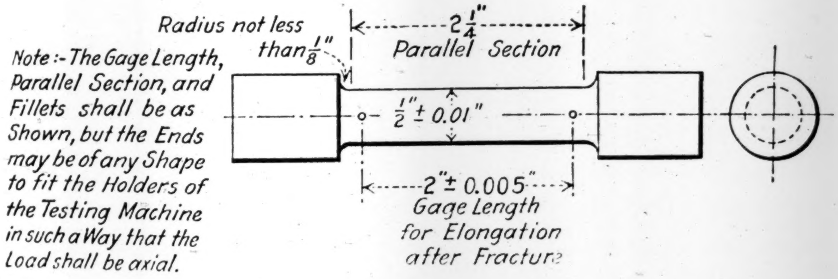
Radius not less than $\frac{1}{8}"$
$2\frac{1}{4}"$ Parallel Section
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
$\frac{1}{2}" \pm 0.01"$
$2" \pm 0.005"$ Gage Length for Elongation after Fracture

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*c*) The yield point in tension shall be determined as the stress producing an elongation under load of 0.5 per cent, that is, 0.01 in. in a gage length of 2 in.

(*d*) *Hardness Test.*—The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 sec. to a finished plane surface. Not less than two hardness tests shall be made for each heat.

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[1] The matters of revising the dimensions of compression test specimens and the method of determining the so-called "deformation limit" are under consideration by Committee E-1 on Methods of Testing. Tests are being made on cylindrical specimens 1 sq. in. in cross-sectional area and 3 in. in height. Committee B-5 on Copper and Copper Alloys, Cast and Wrought, which has written these specifications feels that these specifications with the present compression tests as specified may be satisfactorily used until better compression test specimens are available.—ED.

Test Specimens

7. (*a*) A test bar of the form and dimensions shown in Fig. 1, to be used for the tension test specimen, and a suitable test bar for the compression test specimen, shall be an integral part of the casting, and shall be fed and cooled under the same conditions as the castings.

(*b*) Compression test specimens shall be cylinders 1 sq. in. in cross-sectional area and 1 in. in height.[1]

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests

8. (*a*) One compression test shall be made from each melt for Class A and B castings; and one tension test from each melt for Class D castings. For castings of any grade weighing over 100 lb. finished, the specified tests shall be made for each casting.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

Finish

9. The castings shall be sound, clean, and free from blow-holes, porous places, cracks and other defects.

Inspection

10. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

11. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected, shall be replaced by the manufacturer without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

TENTATIVE SPECIFICATIONS
FOR
ROLLED COPPER-ALLOY BEARING AND EXPANSION PLATES FOR BRIDGE AND OTHER STRUCTURAL USES[1]

A.S.T.M. Designation: B 100 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover rolled copper-alloy plates for use in bridges and other structures for fixed or expansion bearings where motion is slow and intermittent and pressure does not exceed 3000 lb. per sq. in.

Manufacture

2. (*a*) The plates shall be a homogeneous alloy of copper and tin or of copper and silicon and may contain certain other elements as specified in Section 3. The copper shall conform to the requirements of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5),[2] or the "high-resistance lake" grade of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 4)[3] of the American Society for Testing Materials. The plates shall be made from new metal, except that scrap of known composition may be used.

(*b*) The rolled plates may be furnished in either the rolled or annealed condition as required.

Chemical Composition

3. The material shall conform to the following requirements as to chemical composition:

Type A	Tin, min., per cent	3.8
	Phosphorus, max., per cent	0.5
	Sum of above elements plus copper, min., per cent	99.5
Type B	Copper, min., per cent	94.80
	Silicon, per cent	2.70 to 3.75

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 531.

[3] *Ibid.*, p. 526.

One or more of the following elements may be present in Type B copper alloy within the limits specified below:

Manganese, max., per cent	1.50
Zinc, max., per cent	1.75
Iron, max., per cent	1.60
Tin, max., per cent	0.75
Lead, max., per cent	0.05
Copper and silicon plus any of the above elements, min., per cent	99.50

Chemical Analysis

4. (*a*) An analysis shall be furnished by the manufacturer for each 2000 lb. or fraction thereof. The chemical composition of Type A copper alloy as determined by the Tentative Methods of Chemical Analysis of Bronze Bearing Metal (A.S.T.M. Designation: B 46 – 36 T) of the American Society for Testing Materials[1] shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

NOTE.—Methods of chemical analysis for Type B alloy are being prepared by the A.S.T.M. Committee E-3 on Chemical Analysis of Metals.

(*b*) The sample for chemical analysis shall consist of drillings, or millings taken from the plates selected for purpose of tests as specified in Sections 5 and 6, and shall be so taken as to accurately represent material from the full thickness of the plate. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the purchaser, one for the manufacturer, and one for an umpire if necessary.

Physical Properties

5. The plates shall conform to the following requirements as to tensile or compressive properties and hardness. Plates $\frac{3}{4}$ in. or over in thickness may be tested in tension or compression. Plates less than $\frac{3}{4}$ in. in thickness shall be tested in tension.

TENSION	
Tensile strength, min., lb. per sq. in	60 000
Elongation in 2 in., min., per cent	10
COMPRESSION	
Yield strength (0.1 per cent set), min., lb. per sq. in	25 000
Permanent set under 100,000 lb. per sq. in., per cent	6 to 20
HARDNESS	
Plates $\frac{1}{4}$ in. and over in thickness, Brinell number, min	130
Plates less than $\frac{1}{4}$ in. in thickness, Rockwell number, min	B75

Methods of Testing

6. (*a*) Compression test specimens shall be 1 sq. in. in cross-sectional area, and the height shall be the thickness of the plate from which the specimen is taken.

(*b*) The yield strength in compression shall be determined by successive applications and releases of the load until a 0.1 per cent offset is determined.

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 157 (1936).

(*c*) The tension test specimen and method of testing shall conform to the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

(*d*) The Rockwell hardness tests shall be made in accordance with the Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.[2]

(*e*) The Brinell hardness tests (10-mm. ball, 500-kg. load) shall be made in accordance with the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[3]

TABLE I.—PERMISSIBLE VARIATIONS IN THICKNESS AND WEIGHT.

Ordered Weight per Square Foot,[a] lb.	Permissible Variations in Weight, per cent		Ordered Thickness, in.	Permissible Variations in Thickness, per cent	
	Over	Under		Over	Under
PLATES 20 IN. AND UNDER IN WIDTH					
5.0 to 7.5, excl	4.5	3.5	Under $\frac{1}{8}$	9	0
7.5 to 10.0, excl	4	3	$\frac{1}{8}$ to $\frac{3}{16}$, excl	8	0
10.0 to 12.5, excl	4	2.5	$\frac{3}{16}$ to $\frac{1}{4}$, excl	7	0
12.5 to 15.0, excl	3.5	2.5	$\frac{1}{4}$ to $\frac{5}{16}$, excl	6	0
15.0 to 17.5, excl	2.5	2.5	$\frac{5}{16}$ to $\frac{3}{8}$, excl	5	0
17.5 to 20.0, excl	2.5	2.0	$\frac{3}{8}$ to $\frac{7}{16}$, excl	4.5	0
20 or over	2.0	2.0	$\frac{7}{16}$ to $\frac{1}{2}$, excl	4	0
			$\frac{1}{2}$ to $\frac{5}{8}$, excl	3.5	0
			$\frac{5}{8}$ to $\frac{3}{4}$, excl	3	0
			$\frac{3}{4}$ to 1, excl	2.5	0
			1 or over, excl	2.5	0
PLATES OVER 20 IN. IN WIDTH					
All weights	5.0	5.0	All thicknesses	10.0	0

[a] One cubic inch of rolled phosphor bronze (Type A) is assumed to weigh 0.320 lb.; one cubic inch of rolled silicon bronze (Type B) is assumed to weigh 0.310 lb.

Thickness and Weight

7. The thickness of the plates may be specified by weight per square foot or in common or decimal fractions of an inch. The plates shall conform to the requirements in Table I as to permissible variations in weight and thickness.

Finish

8. The plates shall be sound, clean, and free from blowholes, porous

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

[2] *Ibid.*, p. 824.

[3] *Ibid.*, p. 817.

places, cracks, and other defects that would be detrimental or injurious to their use for the purpose intended. The contact surfaces of the plates shall be smooth and level.

Inspection

9. At the option of the purchaser, inspection may be made at the manufacturer's works where the plates are made, or at the point at which they are received. If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

10. Plates which fail to conform to these specifications may be rejected, and if rejected, shall be replaced by the manufacturer, without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

TENTATIVE SPECIFICATIONS
FOR
BRASS SHEET AND STRIP[1]
A.S.T.M. Designation: B 36 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1920; ADOPTED, 1921; REVISED, 1927, 1933; REVISED AND REISSUED AS TENTATIVE, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. (*a*) These specifications cover commercial sheet and slit-edge or rolled-edge strip brasses of the following alloys:

	NOMINAL COMPOSITION	
ALLOY	COPPER, PER CENT	ZINC, PER CENT
No. 1	95	5
No. 2	90	10
No. 3	85	15
No. 4	80	20
No. 5	72	28
No. 6	70	30
No. 7	67	33
No. 8	65	35

(*b*) It should be understood that these specifications are general. Since the different brasses are used for many purposes where the requirements of the operation used are too particular to be specified by any of the ordinary physical tests, it is frequently advisable to submit samples to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations to which the material is to be submitted.

Manufacture

2. (*a*) Brass sheet and strip shall be made from lake or electrolytic copper conforming to the requirements of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (A.S.T.M. Designation: B 4);[2] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (A.S.T.M. Designation: B 5)[3] of the American Society for Testing Materials,

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

These specifications are in effect a revision of, and replace the Standard Specifications for Sheet High Brass (A.S.T.M. Designation: B 36 - 33), 1936 Book of A.S.T.M. Standards, Part I, p. 620, which standard was accordingly discontinued in 1938.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 526.

[3] *Ibid.*, p. 531.

and Grade 3 Zinc, or better, of the Standard Specifications for Slab Zinc (Spelter) (A.S.T.M. Designation: B 6) of the American Society for Testing Materials.[1] Clean new scrap resulting from manufacturing operations upon material complying with these specifications or composed of material of equal purity may be employed.

(*b*) The brass sheet or strip shall be finished by the cold-rolling and the annealing process and may be furnished in either the cold-rolled or annealed condition, as required.

Chemical Composition

3. The brass shall conform to the following requirements as to chemical composition:

Alloy	Copper, per cent	Lead, max., per cent	Iron, max., per cent	Zinc, per cent
No. 1	94.0 to 96.0	0.03	0.05	remainder
No. 2	89.0 to 91.0	0.05	0.05	remainder
No. 3	84.0 to 86.0	0.05	0.05	remainder
No. 4	79.0 to 81.0	0.05	0.05	remainder
No. 5	70.5 to 73.5	0.05	0.05	remainder
No. 6	68.5 to 71.5	0.05	0.05	remainder
No. 7	66.0 to 69.0	0.07	0.05	remainder
No. 8	64.5 to 67.5	0.30	0.05	remainder

Sampling for Chemical Analysis

4. (*a*) Analysis shall be made on each lot of 10,000 lb. or fraction thereof. Drillings, millings, sawings, or clippings shall be taken from at least two separate coils or pieces or from 0.5 per cent of the number of coils or pieces in the lot. Drillings, millings, or sawings shall be taken on material 0.040 in. or more in thickness. Clippings may be taken with shears from metal less than 0.040 in. in thickness. Equal quantities shall be taken from each piece and thoroughly mixed together. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one to be retained.

(*b*) The drill, cutter, saw, or other tool used for sampling the brass sheet or strip shall be thoroughly cleaned. No lubricant shall be used in the operation and the drillings, millings, sawings, or clippings shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

(*c*) In case of dissatisfaction, either party may require that the material be resampled in the presence of representatives of the manufacturer and the purchaser. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 43.

Tempers of Rolled Sheet and Strip

5. The tempers of rolled sheet and strip brasses shall be designated as follows:

TEMPERS, ROLLED SHEET AND STRIP	NOMINAL REDUCTION B. & S. GAGE NO.[a]	APPROXIMATE PERCENTAGE REDUCTION
Quarter hard	1	10.9
Half hard	2	20.7
Three-quarter hard	3	29.4
Hard	4	37.1
Extra hard	6	50.0
Spring	8	60.5
Extra spring	10	68.7

[a] Various ready-to-finish grain sizes may be designated within the limits specified for the several anneals under Section 14 (*a*), if agreed upon between the manufacturer and the purchaser. This agreement should only consider tempers up to and including the three-quarter hard.

Tempers of Annealed Sheet and Strip

6. (*a*) The tempers of annealed sheet and strip brasses shall be designated as follows:[1]

0.015-mm. diameter of average grain
0.025-mm. diameter of average grain
0.035-mm. diameter of average grain
0.050-mm. diameter of average grain
0.070-mm. diameter of average grain
0.120-mm. diameter of average grain

(*b*) Alloys Nos. 5, 6, 7, and 8 are supplied in all of the above tempers. Alloys Nos. 3 and 4 are supplied in the 0.070, 0.050, 0.035 and 0.015-mm. tempers only, and Alloys Nos. 1 and 2 are supplied in the 0.050, 0.035 and 0.015-mm. tempers only.

Physical Properties of Rolled Tempers

7. The tension test shall be standard for all tempers of rolled sheet and strip brasses and acceptance or rejection shall depend only on the tensile strength values specified in Table I. For convenience in testing, Rockwell hardness test values are also given in Table I for some thicknesses. The Rockwell hardness values should be considered as approximate and informatory only.

Tensile Strength of Rolled Tempers

8. The tensile strength of rolled sheet and strip shall be within the limits specified in Table I. Rockwell hardness values corresponding to these strengths in certain thicknesses are given in Table I for informatory purposes only.

Tension Tests

9. (*a*) The tensile properties shall be determined in accordance with the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[2]

(*b*) Ninety-five per cent of the tension tests shall fall within the limits specified in Table I and only one test shall be allowed outside the limits, with maximum variation of 1000 lb. per sq. in. from the limits.

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[1] See Section 14 (*a*) for limits corresponding to these nominal grain size designations.
[2] 1936 Book of A.S.T.M. Standards, Part I, p. 833.

TABLE I.—TENSILE STRENGTH REQUIREMENTS AND ROCKWELL HARDNESS NUMBERS FOR SHEET AND STRIP BRASSES.

Temper	Tensile Strength, lb. per sq. in.		Rockwell Hardness[a]					
			B Scale		F Scale		Superficial 30-T	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
ALLOY NO. 1								
Annealed, 0.050-mm. nominal grain size	......	......	..	..	40[b]	52[b]	..	4
Annealed, 0.035-mm. nominal grain size	......	......	..	..	47[b]	54[b]	..	7
Annealed, 0.015-mm. nominal grain size	......	......	..	..	54[b]	65[b]	7	23
Quarter hard	37 000	47 000	20	50	69[c]	88[c]	20	57
Half hard	42 000	52 000	42	60	82[c]	95[c]	47	61
Three-quarter hard	46 000	56 000	50	65	..	..	55	64
Hard	50 000	59 000	55	67	..	..	60	65
Extra hard	56 000	64 000	63	72	..	..	63	66
Spring	59 500	67 500	68	74	..	..	65	68
Extra spring	61 000	69 000	71	77	..	..	66	69
ALLOY NO. 2								
Annealed, 0.050-mm. nominal grain size	......	......	..	..	50	60	1	16
Annealed, 0.035-mm. nominal grain size	......	......	..	..	54	64	7	21
Annealed, 0.015-mm. nominal grain size	......	......	..	..	62	75	19	39
Quarter hard	40 000	50 000	27	56	70[c]	90[c]	20	61
Half hard	47 000	57 000	50	66	88[c]	98[c]	57	65
Three-quarter hard	52 000	62 000	59	71	..	..	61	66
Hard	57 000	66 000	65	75	..	..	64	68
Extra hard	64 000	72 000	72	79	..	..	67	70
Spring	69 000	77 000	76	81	..	..	68	71
Extra spring	72 000	80 000	78	83	..	..	69	72
ALLOY NO. 3								
Annealed, 0.070-mm. nominal grain size	......	......	..	..	53	60	6	16
Annealed, 0.050-mm. nominal grain size	......	......	..	..	56	63	10	20
Annealed, 0.035-mm. nominal grain size	......	......	..	..	58	66	13	24
Annealed, 0.015-mm. nominal grain size	......	......	..	..	62	79	19	48
Quarter hard	44 000	54 000	33	62	78[c]	94[c]	32	61
Half hard	51 000	61 000	56	71	92[c]	102[c]	60	65
Three-quarter hard	57 000	67 000	65	76	..	..	63	68
Hard	65 000	72 000	72	80	..	..	66	70
Extra hard	71 500	79 500	78	84	..	..	68	71
Spring	78 000	86 000	82	87	..	..	69	72
Extra spring	82 000	90 000	84	89	..	..	70	73
ALLOY NO. 4								
Annealed, 0.070-mm. nominal grain size	......	......	..	..	53	64	2	21
Annealed, 0.050-mm. nominal grain size	......	......	..	..	57	67	8	27
Annealed, 0.035-mm. nominal grain size	......	......	..	..	61	72	16	35
Annealed, 0.015-mm. nominal grain size	......	......	..	..	66	83	25	50
Quarter hard	48 000	58 000	38	65	80[c]	95[c]	39	61
Half hard	54 500	64 500	59	75	93[c]	102[c]	58	66
Three-quarter hard	61 000	71 000	70	80	..	..	64	69
Hard	68 000	77 000	76	85	..	..	68	72
Extra hard	78 000	87 000	82	89	..	..	71	73
Spring	85 000	95 000	86	92	..	..	72	74
Extra spring	89 000	97 000	88	93	..	..	73	75

[a] Rockwell hardness values apply as follows:
The B and F scales apply to metal 0.020 in. in thickness and over,
The 30-T scale applies to metal 0.015 in. in thickness and over, when annealed, and
The 30-T scale applies to metal 0.012 in. in thickness and over, when in rolled tempers.

[b] This alloy in these several annealed tempers is too soft for Rockwell F hardness tests below 0.030 in. in thickness.

[c] The Rockwell B Scale is preferred for testing material in these tempers.

TABLE I.—*Continued.*

Temper	Tensile Strength, lb. per sq. in.		Rockwell Hardness[a]					
			B Scale		F Scale		Superficial 30-T	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
ALLOYS NOS. 5 AND 6								
Annealed, 0.120-mm. nominal grain size	......	......	..	..	50	62	..	18
Annealed, 0.070-mm. nominal grain size	......	......	..	..	54	67	6	27
Annealed, 0.050-mm. nominal grain size	......	......	..	..	61	73	15	34
Annealed, 0.035-mm. nominal grain size	......	......	..	..	65	76	23	41
Annealed, 0.025-mm. nominal grain size	......	......	..	..	67	79	26	46
Annealed, 0.015-mm. nominal grain size	......	......	..	..	72	85	35	53
Quarter hard	49 000	59 000	40	65	..	..	27	63
Half hard	56 500	66 500	60	77	..	..	58	69
Three-quarter hard	64 000	74 000	72	85	..	..	67	72
Hard	71 000	81 000	79	87	..	..	71	75
Extra hard	82 500	91 500	85	91	..	..	75	78
Spring	90 500	99 500	89	93	..	..	77	79
Extra spring	95 000	104 000	91	95	..	..	78	80
ALLOYS NOS. 7 AND 8								
Annealed, 0.120-mm. nominal grain size	......	......	..	..	50	62	..	18
Annealed, 0.070-mm. nominal grain size	......	......	..	..	54	67	6	27
Annealed, 0.050-mm. nominal grain size	......	......	..	..	61	73	15	34
Annealed, 0.035-mm. nominal grain size	......	......	..	..	65	76	23	41
Annealed, 0.025-mm. nominal grain size	......	......	..	..	67	79	28	46
Annealed, 0.015-mm. nominal grain size	......	......	..	..	72	85	35	53
Quarter hard	49 000	59 000	40	65	..	..	25	63
Half hard	55 000	65 000	57	75	..	..	54	68
Three-quarter hard	62 000	72 000	68	80	..	..	65	71
Hard	68 000	78 000	75	85	..	..	69	73
Extra hard	79 000	88 500	82	89	..	..	73	76
Spring	86 000	95 000	85	92	..	..	75	78
Extra spring	89 500	98 500	86	93	..	..	76	79

[a] Rockwell hardness values apply as follows:
The B and F scales apply to metal 0.020 in. in thickness and over,
The 30-T scale applies to metal 0.015 in. in thickness and over, when annealed, and
The 30-T scale applies to metal 0.012 in. in thickness and over, when in rolled tempers.

Tension Test Specimens

10. The test specimens used for making tension tests shall be in accordance with the dimensions shown in Fig. 7, of the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

Number of Tension Tests

11. (*a*) Tension tests shall be made on each lot of 5000 lb. or fraction thereof.

(*b*) The test specimens shall be taken in such numbers and from such locations in each lot of material under test as to be representative of the quality and not less than five samples shall be considered representative.

Rockwell Hardness

12. Rockwell hardness values, indicative of the tensile strength of the brass sheet or strip, are given in Table I for convenience. All Rockwell hardness tests are subject to confirmation by tensile strength tests.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 833.

Rockwell Hardness Tests

13. (*a*) The Rockwell hardness shall be determined in accordance with the Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.[1]

(*b*) The number of hardness tests shall not be less than three on each of the five representative samples selected in accordance with Section 11.

Physical Properties of Annealed Tempers

14. Grain size shall be the standard test for sheet and strip brasses of all thicknesses in annealed tempers and acceptance or rejection shall depend on the grain sizes specified in Section 15. For convenience in testing, Rockwell hardness values for sheet and strip 0.012 in. and over in thickness are given in Table I. The Rockwell hardness values should be considered as approximate and informatory only.

TABLE II.—GRAIN SIZE REQUIREMENTS FOR ANNEALED SHEET AND STRIP BRASSES.

Alloy	Grain Size, mm.		
	Noninal	Minimum	Maximum
No. 1	0.050	0.035	0.090
	0.035	0.025	0.050
	0.015	.....[a]	0.025
No. 2	0.050	0.035	0.090
	0.035	0.025	0.050
	0.015	.....[a]	0.025
No. 3	0.070	0.050	0.100
	0.050	0.035	0.070
	0.035	0.025	0.050
	0.015	.....[a]	0.025
No. 4	0.070	0.050	0.120
	0.050	0.035	0.070
	0.035	0.025	0.050
	0.015	.....[a]	0.025
No. 5, 6, 7 and 8	0.120	0.070	.....
	0.070	0.050	0.100
	0.050	0.035	0.070
	0.035	0.025	0.050
	0.025	0.015	0.035
	0.015	.....[a]	0.025

[a] Although no minimum grain size is required this material must be fully recrystallized.

Grain Size and Hardness of Annealed Tempers

15. (*a*) The average grain size of each of two samples of annealed sheet as determined on a plane parallel to the surface of the sheet or strip shall be within the limits given in Table II. For comparative and informative purposes, corresponding Rockwell hardness values for sheet and strip 0.015 in. and over in thickness are given in Table I.

(*b*) In determining grain size, reference should be made to the standard rules governing the preparation of micrographs and photographic grain size standards for brass appearing in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (A.S.T.M. Designation: E 2) of the American Society for Testing Materials.[1]

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 824.

TABLE III.—PERMISSIBLE VARIATIONS IN THICKNESS, PLUS AND MINUS, IN., FOR MATERIAL UP TO AND INCLUDING 20 IN. IN WIDTH.

Thickness		Widths Up to 8 in., inclusive	Widths Over 8 to 14 in., inclusive	Widths Over 14 to 20 in., inclusive
B. & S. Gage No.	Inch			
0000	0.4600	0.0046	0.0050	0.0055
000	0.4096	0.0044	0.0048	0.0053
00	0.3648	0.0043	0.0047	0.0051
0	0.3249	0.0042	0.0045	0.0049
1	0.2893	0.0040	0.0043	0.0048
2	0.2576	0.0039	0.0042	0.0046
3	0.2294	0.0038	0.0041	0.0045
4	0.2043	0.0037	0.0039	0.0043
5	0.1819	0.0035	0.0038	0.0042
6	0.1620	0.0034	0.0037	0.0041
7	0.1443	0.0033	0.0035	0.0039
8	0.1285	0.0032	0.0034	0.0038
9	0.1144	0.0030	0.0033	0.0037
10	0.1019	0.0029	0.0032	0.0035
11	0.0907	0.0028	0.0030	0.0034
12	0.0808	0.0027	0.0029	0.0033
13	0.0720	0.0025	0.0028	0.0032
14	0.0641	0.0024	0.0027	0.0030
15	0.0571	0.0023	0.0026	0.0029
16	0.0508	0.0022	0.0025	0.0028
17	0.0453	0.0021	0.0024	0.0027
18	0.0403	0.0020	0.0023	0.0026
19	0.0359	0.0018	0.0022	0.0025
20	0.0320	0.0017	0.0021	0.0024
21	0.0285	0.0016	0.0020	0.0023
22	0.0253	0.0015	0.0019	0.0022
23	0.0226	0.0014	0.0018	0.0021
24	0.0201	0.0013	0.0017	0.0020
25	0.0179	0.0012	0.0016	0.0019
26	0.0159	0.0011	0.0016	0.0019
27	0.0142	0.0010	0.0015	0.0018
28	0.0126	0.0009	0.0014	0.0017
29	0.0113	0.0008	0.0013	0.0016
30	0.0100	0.0007	0.0012	0.0015
31	0.0089	0.0006	0.0012	0.0015
32	0.0080	0.0006	0.0011	0.0014
33	0.0071	0.0005	0.0010	0.0013
34	0.0063	0.0005	0.0009	0.0013
35	0.0056	0.0004	0.0009	0.0012
36	0.0050	0.0004	0.0008	0.0011
37	0.0045	0.0004	0.0008	0.0011
38	0.0040	0.0003	0.0007	0.0010

Width

16. (*a*) Permissible variations in width of slit metal shall be as follows:

	PERMISSIBLE VARIATION, IN.			
THICKNESS, IN.	WIDTHS UP TO 2 IN., INCLUSIVE	WIDTHS OVER 2 TO 8 IN., INCLUSIVE	WIDTHS OVER 8 TO 14 IN., INCLUSIVE	WIDTHS OVER 14 TO 20 IN., INCLUSIVE
Over 0.004 to 0.032, inclusive	0.010	0.015	0.020	0.025
Over 0.032 to 0.132, inclusive	0.020	0.025	0.030	0.035

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 763.

(*b*) Permissible variations in width of square sheared metal shall be as follows:

THICKNESS, IN.	PERMISSIBLE VARIATIONS, IN.
Up to 0.125, inclusive	+ 0.064 in. – 0.000 in.
Over 0.125	+ 0.128 in. – 0.000 in.

(*c*) Permissible variations in width of sawed metal in all gages shall be plus 0.032 in., minus 0.000 in.

(*d*) Permissible variations in width of rolled-edge metal shall be as follows:

	PERMISSIBLE VARIATIONS, IN.			
THICKNESS, IN.	WIDTHS UP TO 0.375 IN., INCLUSIVE	WIDTHS OVER 0.375 TO 0.875 IN., INCLUSIVE	WIDTHS OVER 0.875 TO 2.0 IN., INCLUSIVE	WIDTHS OVER, 2.0 TO 8.0 IN., INCLUSIVE
Over 0.004 to 0.132, inclusive	0.005	0.008	0.010	0.015
Over 0.132 to 0.250, inclusive	0.007	0.010	0.015	0.025

NOTE.—All variations in width shall be *over* the specified width unless otherwise specified by the purchaser.

Straightness

17. The edgewise curvature (depth of chord) in a 72-in. length of metal shall not exceed the following:

When shipped as sheet or strip	0.5 in.
When shipped in coils	1 in.

Thickness

18. The standard method of specifying thickness shall be either in terms of Brown & Sharpe gage or corresponding decimal fractions of an inch. The tolerances shall be those of the corresponding group of B. & S. gage sizes shown in Tables III and IV.

TABLE IV.—PERMISSIBLE VARIATIONS AT ANY POINT IN THE THICKNESS OF SHEET AND STRIP, PLUS OR MINUS, PER CENT FOR MATERIAL OVER 20 IN. IN WIDTH.

WIDTH, IN.	THICKNESSES UP TO 0.025 IN., INCLUSIVE	THICKNESSES OVER 0.025 TO 0.050 IN., INCLUSIVE	THICKNESSES OVER 0.050 TO 0.100 IN., INCLUSIVE	THICKNESSES OVER 0.100 IN.
Over 20 to 36, inclusive	9.0	7.5	7.5	5.0
Over 36 to 48, inclusive	15.0	10.0	7.5	7.5
Over 48 to 60, inclusive	15.0	12.5	10.0	7.5
Over 60	....	15.0	12.5	10.0

Length

19. (*a*) Metal may be furnished in coils or flat sheet or strips as required. Coils shall consist of not more than three lengths, no one of which shall be less than 10 ft. in length. When furnished in coils or flat sheet or strips cut to length, a variation of 0.250 in. over the specified length will be permitted on standard lengths.

NOTE.—All length variations shall be over the specified lengths unless prescribed otherwise by the purchaser.

Acceptable Short Lengths

20. (*a*) Flat sheet or strip lengths shall be in accordance with the following regular practice:

Nominal or Stock Length Ordered, ft.	Required Minimum Percentage by Weight of Stock Lengths	Maximum Permissible Percentage by Weight of Short Lengths				
		In Lengths 10 ft. and Over	In 8 to 10-ft. Lengths	In 6 to 8-ft. Lengths	In 4 to 6-ft. Lengths	In 2 to 4-ft. Lengths
10 to 12	60	40	30	20	10	..
10	60	..	40	30	20	10
8	70	..	..	30	20	10
6	80	..	..	..	20	10

(*b*) When special lengths are required, they shall be specified in the order.

Finish

21. The brass sheet and strip shall be free from injurious external and internal defects of a nature which will interfere with the purpose for which it is intended. It shall be well cleaned and free from dirt.

Inspection

22. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection

23. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

TENTATIVE SPECIFICATIONS
FOR
COPPER AND COPPER-ALLOY SEAMLESS CONDENSER TUBES AND FERRULE STOCK[1]

A.S.T.M. Designation: B 111 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover seamless tubes and ferrule stock of various copper alloys, for use in surface condensers, evaporators, and heat exchangers.

2. The tubes shall be cold worked to size from an alloy made from lake or electrolytic copper in combination with one or more of the following elements conforming to the requirements of standard specifications of the American Society for Testing Materials, as follows:

(*a*) *Lake or Electrolytic Copper.*—Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (A.S.T.M. Designation: B 4)[2] or for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (A.S.T.M. Designation: B 5).[3]

(*b*) *Zinc, No. 1 High Grade.*—Standard Specifications for Slab Zinc (Spelter) (A.S.T.M. Designation: B 6).[4]

(*c*) *Tin.*—"Straits" tin or its equivalent.

(*d*) *Nickel, Electrolytic Grade.*—Standard Specifications for Nickel (A.S.T.M. Designation: B 39).[5]

(*e*) *Aluminum, Grade 99.5.*—Standard Specifications for Aluminum Ingots for Remelting (A.S.T.M. Designation: B 24).[6]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

These specifications are in effect a revision and consolidation of, and replace the former Standard Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 33), and for Seamless Muntz Metal Condenser Tubes and Ferrule Stock (B 56 – 33), and also the former Tentative Specifications for Seamless Copper-Nickel Alloy Condenser Tubes and Ferrule Stock (B 104 – 36 T), which specifications were accordingly discontinued in 1937.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 526.

[3] *Ibid.*, p. 531.

[4] 1937 Supplement to Book of A.S.T.M. Standards, p. 43.

[5] 1936 Book of A.S.T.M. Standards, Part I, p. 684.

[6] *Ibid.*, p. 524.

(*f*) Scrap shall not be used except such as may result from the manufacture of articles of the same composition.

Manufacture

3. (*a*) Condenser tubes shall be so processed as to enable the tubes to pass the physical and metallographic tests prescribed in these specifications.

(*b*) Copper or arsenical copper tubes shall be supplied in any one of the following tempers, unless otherwise specified:

Light-drawn temper
Hard-drawn temper
Hard-drawn temper, end annealed

Tubes supplied in a light-drawn temper shall pass the expanding test specified in Section 7 (*a*).

(*c*) Tubes for ferrule stock shall be annealed sufficiently to be fully recrystallized, but are not subject to the expanding test specified in Section 7.

Chemical Composition

4. The material shall conform to the following requirements as to chemical composition (see Explanatory Note):

Alloy	Copper,[a] per cent	Tin, per cent	Aluminum, per cent	Nickel,[c] per cent	Lead, max., per cent	Iron, max., per cent	Zinc, per cent	Manganese, per cent	Phosphorus, max., per cent	Arsenic, per cent
Muntz metal[b]	59.0 to 63.0	....	....	....	0.3	0.07	remainder	......	......	....
Admiralty[b]	70.0 min.	0.90 to 1.20	....	....	0.075	0.06	remainder	......	......	....
Red brass	84.0 min.	....	....	....	0.075	0.06	remainder	......	......	....
Aluminum brass[b]	76.0 min.	1.25 max.	1.75 to 2.50	1.25 max.	0.075	0.06	remainder	......	......	....
Aluminum bronze	93.5 min.	....	5.00 min.	....	.....	.....	....	......	......	....
70-30 copper-nickel	remainder	1.50 max.	....	29.0 to 33.0	0.05	0.5	1.0 max.	1.0 max.	......	....
80-20 copper-nickel:										
Type A	remainder	1.0 max	....	19.0 to 23.0	0.05	0.5	1.0 max.	1.0 max.	......	....
Type B	remainder	1.0 max.	....	19.0 to 23.0	0.05	0.5	3.0 to 6.0	1.0 max.	......	....
Copper	99.90 min.	....	....	....	.....	.....	....	......	0.035	....
Arsenical copper	99.20 min.	....	....	....	.....	.....	....	......	......	0.15 to 0.75

[a] Silver counting as copper.
[b] If agreed upon between the manufacturer and the purchaser, these alloys may contain a maximum of 0.25 per cent antimony or maximum of 0.1 per cent arsenic.
[c] Cobalt counting as nickel.

Sample for Chemical Analysis

5. The sample for chemical analysis shall consist of drillings, millings, or clippings taken from two separate tubes from each lot of 600 tubes or fraction thereof, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

Microscopic Examination

6. (*a*) A microscopic examination of the annealed tubes selected for test, except those of Muntz metal, shall show sufficient annealing for complete recrystallization with a uniform grain size not in excess of 0.045 mm.

in average diameter. Muntz metal tubes shall have been so annealed that when magnified at 75 diameters a properly prepared specimen shall show uniform and complete recrystallization. This requirement does not apply to hard-drawn tubes, end annealed, in which case no microscopic examination is required.

(*b*) The test specimen for the microscopic examination shall be a radial longitudinal section of the tube made by cutting along a plane containing the longitudinal axis of the tube

(*c*) The determination of grain size shall be made by comparison of micrographs representing the specimens selected for test with micrographs of standard specimens for which the grain size has been accurately determined. The magnification in all such micrographs shall be 75 diameters. The standard micrographs shall be taken from specimens, the grain size of which has been determined by Jeffries' method for grain size measurements, as described in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (A.S.T.M. Designation: E 2) of the American Society for Testing Materials,[1] at a magnification of 250 diameters. Reproductions of micrographs so prepared are shown in Plate II in the Standard Rules E 2.[1]

Expanding Test

7. (*a*) The annealed tubes selected for test shall be capable of standing the following test without showing signs of cracking or rupture: A pin having a taper of 1½ in. per ft. shall be driven into the tube until the inside diameter at one end has been increased 20 per cent. The foregoing applies to all alloys except Muntz metal and copper nickel, which shall be required to withstand an expansion of 15.0 and 30.0 per cent, respectively.

(*b*) Hard-drawn tubes, not end annealed, are not subject to this test. When tubes are specified end annealed, this test is required and shall be made on the annealed ends.

Strain Test

8. A test specimen 6 in. in length shall stand, without cracking, an immersion for 15 min. in an aqueous mercurous-nitrate solution containing 100 g. of mercurous nitrate and 13 ml. of HNO_3 (sp. gr. 1.42) per liter of solution. In the case of hard-drawn tubes, end-annealed, the test specimen shall be cut from the central unannealed portion of the tube.

Hydrostatic Test

9. Each tube shall stand an internal hydrostatic pressure of 1000 lb. per sq. in., without leakage.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 763.

Number of Tests

10. Tubes shall be grouped into lots of 600 tubes or fraction thereof. Two tubes shall be selected from each lot and subjected to the physical tests specified in Sections 6 to 8, inclusive.

Retests

11. If any test specimen representing a lot fails to meet the requirements of Sections 4, 6 and 7, two additional specimens, at the option of the manufacturer, may be taken as before, and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

Permissible Variations in Dimensions and Weight

12. (*a*) *Diameter.*—The outside diameter of the tubes shall not vary from that specified by more than the following amounts, as measured by "go" and "no go" ring gages:

NOMINAL DIAMETER, IN.	PERMISSIBLE VARIATION,[a] IN.
Up to 0.500, incl	±0.002
Over 0.500 to 0.740, incl	±0.0025
Over 0.740 to 1.000, incl	±0.003
Over 1.000 to 1.250, incl	±0.0035
Over 1.250 to 1.500, incl	±0.004

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[a] For copper-nickel tubes the permissible variation in each size class shall be ±0.0005 in. larger than the tolerances in the above table.

(*b*) *Thickness.*—No tube at its thinnest point shall be less than the thickness specified.

(*c*) *Length.*—The length shall be not less than that ordered, when measured at a temperature of 20 C. (68 F.), but may be more than that ordered by the amounts in the following table:

ORDERED LENGTH, FT.	PERMISSIBLE VARIATION, IN.
Up to 15, incl	$+\frac{1}{16}$
Over 15 to 20, incl	$+\frac{3}{32}$
Over 20	$+\frac{1}{8}$

(*d*) *Weight.*—No lot of tubes shall exceed the calculated weight by more than 5.0 per cent. One cubic inch of the various alloys covered by these specifications shall be assumed to weigh:

ALLOY		UNIT WEIGHT, LB. PER CU. IN.
Muntz metal		0.303
Admiralty		0.308
Red brass		0.316
Aluminum brass		0.301
Aluminum bronze		0.295
70–30 copper-nickel		0.323
80–20 copper-nickel	Type A	0.323
	Type B	0.320
Copper		0.323
Arsenical copper		0.323

Workmanship

13. The tubes shall be round, straight, and uniform in thickness throughout. They shall be free from cracks, seams, slivers, scale, and other surface defects, both inside and outside.

Finish

14. All tubes shall be bright annealed or acid cleaned after the final annealing, unless otherwise specified.

Inspection

15. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture, prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

EXPLANATORY NOTE

NOTE.—Individual manufacturers of condenser tubes offer modifications of the types of alloys covered by these specifications. Some of these are proprietary alloys and many are sold under a trade-mark. These specifications may be considered as covering these special alloys when the change in analysis is specifically agreed upon by both the manufacturer and the purchaser, or when the purchaser waives adherence to stipulations of Section 4.

Tentative Specifications for
BRAZING SOLDER[1]

A.S.T.M. Designation: B 64 – 38 T

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1927; Adopted, 1928; Revised and Reissued as Tentative, 1938.[2]

Scope

1. These specifications cover two grades of granular brazing solder, in the following three classifications as described in Sections 6, 7, and 8, respectively:

Round-Grain Solder,
Long-Grain Solder, and
Lump Solder

Manufacture

2. These solders shall be prepared by grinding or other process of granulation.

Chemical Composition

3. The material shall conform to the following requirements as to chemical composition:

	50-50 Grade	52-48 Grade
Copper, per cent	50.00 to 53.00	52.00 to 55.00
Lead, max., per cent	0.50	0.50
Iron, max., per cent	0.10	0.10
Zinc, per cent	remainder	remainder

Chemical Analysis

4. A composite sample of not less than 2 oz. shall be taken from each 2000 lb., or fraction thereof, in the shipment by taking, as nearly as possible, equal parts from each package or container. Samples shall consist of the grains as prepared for round-grain and long-grain solder, or, in the case of lump solder of material obtained by drilling, milling, or sawing the lumps. The samples shall be clean and free from oil, dirt, oxide, or other foreign material.

Sampling

5. In the case of dissatisfaction, the solder shall be sampled in the presence of representatives of both the manufacturer and the purchaser. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

Round-Grain Solder

6. Round-grain solder shall be furnished according to the following classification and sizes:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

FINE ROUND-GRAIN SOLDER

Retained on a 2380-micron (No. 8) sieve: none
Retained on a 420-micron (No. 40) sieve: not more than 5 per cent
Retained on a 149-micron (No. 100) sieve: not less than 90 per cent
Passing a 149-micron (No. 100) sieve: not more than 5 per cent

COARSE ROUND-GRAIN SOLDER

Retained on a 2380-micron (No. 8) sieve: not more than 8 per cent
Retained on a 420-micron (No. 40) sieve: not less than 90 per cent
Passing a 420-micron (No. 40) sieve: not more than 2 per cent

MIXED ROUND-GRAIN SOLDER

Mixed round-grain solder shall be a mixture of all grains from fine to coarse.

Long-Grain Solder

7. Long-grain solder shall be furnished in the following sizes:

(*a*) *Fine Long-Grain Solder.*—Fine long-grain solder shall consist of fairly uniform grains about $\frac{1}{2}$ in. in length and about $\frac{1}{16}$ in. in maximum diameter.

(*b*) *Coarse Long-Grain Solder.*—Coarse long-grain solder shall consist of irregular aggregates of long grains about $\frac{1}{4}$ to 1 in. in length and about $\frac{1}{4}$ in. in maximum diameter.

(*c*) *Mixed Long-Grain Solder.*—Mixed long-grain solder shall be a mixture of all grains from fine to coarse.

Lump Solder

8. Lump solder shall consist of irregular lumps of long-grain solder, about 2 in. to 4 in. in dimensions.

Packing

9. (*a*) Round-grain and long-grain solder shall be packed in strong wooden boxes, not to exceed 300 lb. per box. The fine-grain solders shall be packed in paper-lined wooden boxes. Lots weighing less than 100 lb. shall be packed in tinned containers, enclosed in wooden boxes unless otherwise specified.

(*b*) Lump solder shall be packed in strong barrels or boxes, not to exceed 500 lb. per container.

(*c*) The coarse-grain or mixed solders may be packed in strong barrels when so specified.

Impurities

10. The brazing solder shall be free from oxide, dirt, or any foreign material which will impair its working qualities.

Marking

11. Each package shall be legibly marked with the grade and size, the weight of the material, brand or trademark of the manufacturer, and the contract or purchase order number.

Inspection

12. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the solder is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

13. Solder which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

ENDORSED BY
AMERICAN FOUNDRYMEN'S ASSOCIATION

Tentative Specifications for
PHOSPHOR TIN[1]

A.S.T.M. Designation: B 51 - 38 T

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1927; REVISED AND REISSUED AS TENTATIVE, 1938.[2]

Scope

1. These specifications cover phosphor tin in one grade.

Material

2. The manufacturer shall use pure or refined tin of uniform quality throughout in the manufacture of phosphor tin.

3. The manufacturer or seller shall furnish phosphor tin as ingots in the form of notched slabs of a size that can be handled conveniently.

Chemical Composition

4. The material shall conform to the following requirements as to chemical composition:

Phosphorus, min., per cent	3.50
Phosphorus plus tin, min., per cent	99.50

Sampling

5. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawings shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled or sawed completely through, or one-half through from the top and bottom, the surface material being rejected.

Uniformity

6. Phosphor tin shall be clean, free from defects, and uniform in quality.

Marking

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and the heat may be identified. Marking may be done either by stamping or painting.

Claims

8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant and the results of tests by the purchaser shall be given. The manufacturer shall within ten days of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 5. Samples so taken shall

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of metal meeting these specifications.

ENDORSED BY
AMERICAN FOUNDRYMEN'S ASSOCIATION

Tentative Specifications for PHOSPHOR COPPER[1]

A.S.T.M. Designation: B 52 - 38 T

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1924; Adopted, 1927; Revised and Reissued as Tentative, 1938.[2]

Scope

1. These specifications cover phosphor copper in two grades, as follows:

Grade A, and
Grade B.

Material

2. The manufacturer shall use pure or refined metal (Note), with or without the addition of scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.

Note.—For the quality of copper to be used reference should be made to the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars A.S.T.M. Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5) of the American Society for Testing Materials.[3]

3. The manufacturer or seller shall furnish phosphor copper as ingots in the form of notched slabs, weighing from 15 to 20 lb., unless otherwise specified in the purchase order.

Chemical Composition

4. The material shall conform to the following requirements as to chemical composition:

	Grade A	Grade B
Phosphorus, min., per cent..	14.0	10.0
Phosphorus plus copper, min., per cent...........	99.75	99.75
Iron, max., per cent.......	0.15	0.15

Sampling

5. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawings shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled or sawed completely through, or one-half through from the top and bottom, the surface material being rejected.

Uniformity

6. Phosphor copper shall be clean, free from defects, and uniform in quality.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

[3] 1936 Book of A.S.T.M. Standards, Part I, pp. 526, 531.

Marking

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab, ingot, or container by which the manufacturer and the heat may be identified. Marking may be done either by stamping or painting.

Claims

8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of tests by the purchaser shall be given. The manufacturer shall within ten days of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of metal meeting these specifications.

ENDORSED BY
AMERICAN FOUNDRYMEN'S ASSOCIATION

Tentative Specifications for
SILICON COPPER[1]

A.S.T.M. Designation: B 53 – 38 T

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1927; REVISED AND REISSUED AS TENTATIVE, 1938.[2]

Scope

1. These specifications cover silicon copper in three grades, as follows:

Grade A,
Grade B, and
Grade C.

Material

2. The manufacturer shall use pure or refined metal (Note), with or without the addition of scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.

NOTE.—For the quality of copper to be used reference should be made to the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 4) or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5) of the American Society for Testing Materials.[3]

3. The manufacturer or seller shall furnish silicon copper in the form of lumps, ingots, or notched slabs of a size that can be handled conveniently.

Chemical Composition

4. The material shall conform to the following requirements as to chemical composition:

	GRADE A	GRADE B	GRADE C
Silicon, per cent	10 to 12	17 to 21	28 to 32
Tin, max., per cent	0.25	0.25	0.25
Zinc, max., per cent	0.25	0.25	0.25
Iron, max., per cent	0.75	0.75	0.75
Aluminum, max., per cent	0.25	0.25	0.25
Copper	remainder	remainder	remainder
Sum of copper, silicon and iron contents, per cent	99.4	99.4	99.4

Sampling

5. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawings shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled or sawed completely through, or one-half through

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

[3] 1936 Book of A.S.T.M. Standards, Part I, pp. 526, 531.

from the top and bottom, the surface material being rejected.

Uniformity

6. Silicon copper shall be clean, free from defects, and uniform in quality.

Marking

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab, ingot, or container by which the manufacturer and the heat may be identified. Marking may be done either by stamping or painting.

Claims

8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of tests by the purchaser shall be given. The manufacturer shall within ten days of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of metal meeting these specifications.

TENTATIVE SPECIFICATIONS

FOR

ZINC-BASE ALLOY DIE CASTINGS[1]

A.S.T.M. Designation: B 86 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1931; REVISED, 1933, 1934, 1938.

By publication of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing the specifications against liability for infringement of Letters Patent nor assume any such liability, and such publication should not be construed as a recommendation of any patented or proprietary application that may be involved.

Scope

1. These specifications cover commercial die castings, die cast from zinc-base alloys. Three alloy compositions are specified, designated alloys Nos. XXI[2], XXIII, and XXV.

MANUFACTURE

Process

2. (*a*) The alloys may be made by any approved method.

(*b*) The casting shall be of uniform quality and no scrap shall be used other than the sprues, gates, rejected castings, etc., of the particular alloy, which are produced in the manufacturer's own plant. The rejected castings used shall be free from finishes, solder, or inserts which may contaminate the alloy.

Base Metal

3. The base metal for the alloys shall be slab zinc conforming to the requirements for the special high grade of the Standard Specifications for Slab Zinc (Spelter) (A.S.T.M. Designation: B 6) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-6 on Die-Cast Metals and Alloys.

[2] This alloy designation corresponds to the number used in the investigation on zinc-base die-casting alloys carried out under the jurisdiction of Committee B-6 on Die-Cast Metals and Alloys (formerly Subcommittee XV on Die-Cast Metals and Alloys of Committee B-2 on Non-Ferrous Metals and Alloys). See *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 192 (1929).

[3] 1937 Supplement to Book of A.S.T.M. Standards, p. 43.

CHEMICAL COMPOSITION AND TESTS

Chemical Composition

4. The alloys shall conform to the following requirements as to chemical composition:

	ALLOY NO. XXI	ALLOY NO. XXIII	ALLOY NO. XXV
Copper, per cent	2.5 to 3.5	0.10, max.	0.75 to 1.25
Aluminum, per cent	3.5 to 4.5	3.5 to 4.3	3.5 to 4.3
Magnesium, per cent	0.02 to 0.10	0.03 to 0.08	0.02 to 0.08
Iron, max., per cent	0.100	0.100	0.100
Lead, max., per cent	0.007	0.007	0.007
Cadmium, max., per cent	0.005	0.005	0.005
Tin, max., per cent	0.005	0.005	0.002
Zinc, per cent	remainder	remainder	remainder

Sampling

5. (*a*) The sample for chemical analysis may be taken either by sawing, drilling, or milling the casting or tension test specimen, and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

PHYSICAL PROPERTIES AND TESTS

Expansion

6. (*a*) The average expansion of any five or more castings or test specimens after being exposed to water vapor at 95 C. for 10 days shall not exceed the following values:

	ALLOY NO. XXI	ALLOY NO. XXIII	ALLOY NO. XXV
Expansion per inch, max., in	0.0025	0.0010	0.0010

NOTE.—A maximum expansion of the amount permitted in 1 in. is allowable in any dimension less than 1 in. Dimensions shall be measured across solid sections of the casting.

(*b*) The humidity cabinet shall be vented, and shall contain no wood or organic matter. The specimens shall be supported at points outside of the test section by glass, porcelain, zinc, or zinc-coated metal.

Optional Tests

7. Unless specified in the order or specifically guaranteed by the manufacturer, acceptance of castings under these specifications shall not depend on physical properties determined by tension or impact tests.

Physical Properties

8. When specified, the test specimens representing the alloy shall conform to the following requirements as to physical properties in the condition as received from the manufacturer:

	AVERAGE OF SPECIMENS (See Section 11)			INDIVIDUAL SPECIMENS		
	ALLOY No. XXI	ALLOY No. XXIII	ALLOY No. XXV	ALLOY No. XXI	ALLOY No. XXIII	ALLOY No. XXV
Tensile strength, min., lb. per sq. in.	44 000	35 000	40 000	35 000	30 000	32 000
Elongation in 2 in., min., per cent	2.0	3.0	2.0	0.5	2.0	0.5
Charpy impact, min., ft-lb.	6.0	12.0	12.0	4.0	8.0	8.0

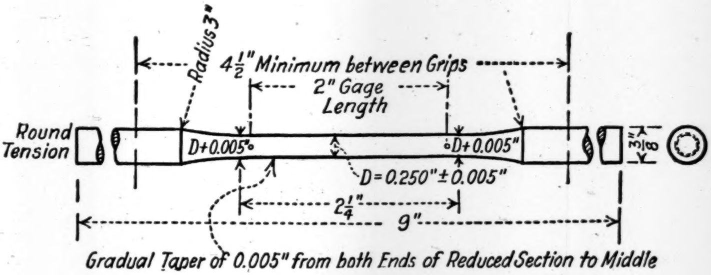
Radius 3"
4½" Minimum between Grips
2" Gage Length
Round Tension
D+0.005"
D+0.005"
D=0.250"±0.005"
2¼"
9"
3/8
Gradual Taper of 0.005" from both Ends of Reduced Section to Middle

FIG. 1.—Round Tension Test Specimen.

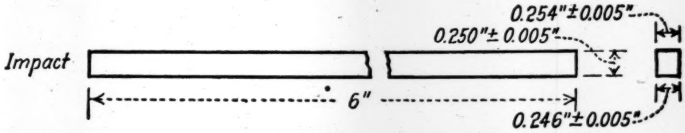
0.254"±0.005"
0.250"±0.005"
Impact
6"
0.246"±0.005"

FIG. 2.—Test Bar from Which Two Charpy Impact Test Specimens are Cut.

Stability

9. When specified, the test specimens representing the alloy shall conform to the following requirements as to physical properties after being exposed to water vapor at 95 C. for 10 days as specified in Section 6.

	AVERAGE OF SPECIMENS (see Section 11)		
	ALLOY No. XXI	ALLOY No. XXIII	ALLOY No. XXV
Tensile strength, min., lb. per sq. in.	30 000	30 000	30 000
Elongation in 2 in., min., per cent	0.5	1.5	1.0
Charpy impact, min., ft-lb	0.75	12.0	6.0

Test Specimens

10. (*a*) The test specimens shall be die cast according to the dimensions shown in Figs. 1 and 2 and shall be tested without machining. No ejector pins shall be used on reduced sections. Specimens shall be removed from dies as soon as cast and cooled in still air with gates attached.

(*b*) Impact test specimens shall be made by cutting the 6-in. bar into two pieces 3 in. in length. The anvil of the testing machine shall have a 40-mm. span. The larger width of the test specimen shall be placed against the anvil.

Defective Bars

(*c*) In case any of the test specimens contain a flaw or flaws which results in failure of the alloy to meet the specifications, the manufacturer and purchaser shall agree upon the selection of specimens for retests, or the defective bars shall be disregarded.

Number of Tests

11. Five tension specimens and 10 impact specimens (cut from 5 bars) shall be tested.

Soundness

12. Heavy section die castings are subject to spongy centers. The extent of this sponginess if objectionable shall be mutually agreed upon by the manufacturer and purchaser for each individual casting.

WORKMANSHIP AND FINISH

Finish

13. The die casting shall be produced free from cracks and other disfiguring blemishes.

REJECTION

Rejection

14. Die castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected the manufacturer's responsibility shall be limited to replacing rejected parts without charge to the purchaser.

TENTATIVE METHOD FOR BEND TESTING OF WIRE[1]

(WIRE FOR RADIO TUBES, AND INCANDESCENT LAMPS)

A.S.T.M. Designation: B 113 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method of test is intended to evaluate the "temper" of wire for radio tubes and incandescent lamps, and for electrical resistance purposes. It is intended for use on wire from approximately 0.010 to 0.117 in. (0.25 to 3.0 mm.) in diameter.[2]

Nature of Bend Test

2. The test comprises clamping a specimen of wire rigidly at one end, subjecting it to a bending force and measuring the angle of bend. The bending force is applied by means of a loading system such as a pivoted, weighted arm actuated by gravity and carrying a "bending die" (see Fig. 1) which maintains contact with the specimen during the bending operation.

NOTE.—Thus the energy absorbed by the specimen may be calculated from a knowledge of the magnitude and location of the unbalanced weights and the angle through which the moving element turns from a predetermined initial position until brought to rest by the resistance of the specimen.

Apparatus

3. The apparatus shall include the following elements:

(*a*) A frame having sufficient weight and rigidity to prevent appreciable vibration and carrying a scale for indicating angular movements of the loading system.

(*b*) A loading system comprising a carrier pivoted for rotation about a horizontal axis, adjustable weights, bending die and pointer; the whole so constructed as to act as a weighted beam serving to apply the bending load to the specimen.

(*c*) Means for adjusting and indicating the torque exerted by the loading system when in the initial position.

(*d*) Means for ensuring that when the loading system is in its initial position ready for making a test its center of gravity will lie within plus or minus 1 deg. of the horizontal plane passing through the axis of rotation.

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[1] Under the standardization procedure of the Society, this proposed method of test is under the jurisdiction of the A.S.T.M. Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys.

[2] An investigation is being made to determine whether a correlation can be found between this method and other bend test methods, such as Methods A and C as outlined in the Appendix to the 1936 Annual Report of Committee B-4, see *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 162 (1936).

(*e*) The loading system shall have a moment of inertia such that when making a test it will reach approximately its final position in not less than 0.2 nor more than 3.0 sec. after release.

(*f*) Release mechanism for holding the loading system accurately at its initial position and freeing it at will without impulse.

(*g*) Means for measuring the angular position and range of motion of the loading system in bending the specimen.

(*h*) A bending die conforming to the dimensions shown in Fig. 2.

(*i*) A specimen clamp to hold the specimen in position for test (see Fig. 1) and attached to the frame in such a way as to permit it to be rotated about a horizontal axis (see Paragraph (*j*)) and fixed in a desired position.

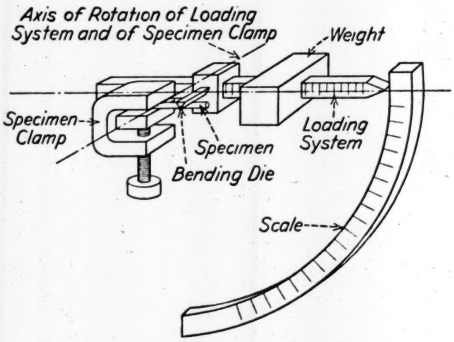

FIG. 1.—Schematic Diagram of Bend Test Machine.

(*j*) Means for bringing the specimen into contact with the bending die when the latter is in its initial position by rotating the specimen clamp about a horizontal axis coinciding with the axis of rotation of the loading system and lying in the intersection of the planes defined by the clamping face of the fixed jaw and the faces "A" of the jaws of the specimen clamp (see Fig. 2).

(*k*) Means for leveling the apparatus within 1.0 deg.

Test Specimen

4. (*a*) The test specimen shall be long enough to permit it to be securely held in the specimen clamp. In general, the clamped portion shall be not less than $\frac{3}{8}$ in. in length. The test specimen shall be of sufficient length so that it will always extend beyond the edge of the bending die.

(*b*) The specimen shall not be straightened prior to test. In order to secure samples representative of the original material, great care shall be taken to avoid any plastic deformation of the wire in removing it from the spool or coil, and in subsequent handling. Even slight bending may markedly alter the temper of the wire.

Measurement of Specimen Diameter

5. (*a*) Specimens of clean wire shall be carefully straightened by rolling lightly between plane surfaces or by other means which do not change the diameter. The diameter shall then be measured with a 1-in. machinist's micrometer having anvil and spindle surfaces 0.250 in. in diameter, and equipped with vernier and ratchet, or by other method as agreed upon. The average of the three measurements at intervals of approximately 60 deg. around the wire shall be taken as the diameter of the specimen.

(*b*) Specimens which have been subjected to straightening treatment shall not be used as bend test specimens.

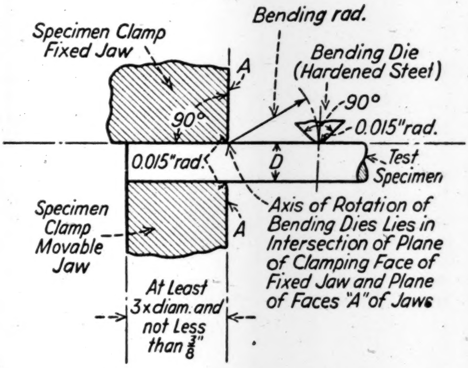
Bending rad.
Specimen Clamp Fixed Jaw
A
Bending Die (Hardened Steel)
90°
90°
0.015" rad.
0.015" rad.
D
Test Specimen
Specimen Clamp Movable Jaw
A
Axis of Rotation of Bending Dies Lies in Intersection of Plane of Clamping Face of Fixed Jaw and Plane of Faces "A" of Jaws
At Least 3 × diam. and not Less than $\frac{3}{8}$"

FIG. 2.—Schematic Diagram of Specimen Clamp and Bending Die.

Procedure

6. (*a*) *Leveling the Machine.*—The machine shall be leveled to bring the plane passing through the axis of rotation and the center of gravity of the weighted loading system to within 1.0 deg. of the horizontal when the latter is in the initial position.

(*b*) *Balancing the Carrier.*—The bending die shall be set at the required position. The loading weights shall be removed. Tapping the machine lightly to minimize the effects of bearing friction, the carrier shall be adjusted to balance in both the horizontal position and at about 35 deg. below the horizontal.

(*c*) *Checking for Friction.*—The carrier shall be weighted to provide an initial turning moment of 5 cm-g. When released without a specimen in place it shall rotate steadily through an angle of not less than 40 deg. Failure to do so shall be regarded as indicating excessive friction. Such a condition shall be corrected before making tests.

(*d*) *Checking Position of Center of Gravity.*—The bending die and weights shall be placed as for making tests and the loading system allowed to swing freely in its lowest position. This position shall correspond to a movement of 90 ± 1 deg. from the initial position. In the event that the range of free movement of the loading system is less than 90 deg. the whole machine shall be rotated through a known angle about a horizontal axis parallel to the axis of rotation of the loading system until the latter swings free. Knowing the angle through which the machine has been rotated and the final position of the pointer with reference to the scale it can be determined whether the center of gravity lies within the required limits. If not, appropriate adjustments shall be made.

(*e*) *Setting of Bending Die.*—The bending die shall be adjusted on the carrier so that the center line of the surface of the former which makes contact with the specimen is distant from the axis of rotation of the specimen clamp by a fixed distance of 0.197 in. (5 mm.), 0.394 in. (1 cm.), 0.688 in. (2 cm.), or 1.376 in. (4 cm.) as may be agreed upon (see Fig. 2). This distance is the bending radius.

(*f*) *Mounting of Specimen.*—The loading system shall be held in its initial position. The specimen shall then be fastened in the clamp and the latter rotated until contact with the bending die is just made. Means shall be provided and used to indicate contact between the specimen and the bending die.

(*g*) *Adjustment of Load.*—Under the influence of an unbalanced weight applied to the loading system, the latter moves due to gravity when released, causing the specimen to bend. The weighting shall be as agreed upon for the material under test and shall give a net movement of the loading system of approximately 30 deg. The angle of bend shall be taken as that indicated by the pointer in the final position after elastic oscillations have ceased. Continued slow sagging may occur with some materials. Should this be a cause of significant uncertainty, a time interval of 30 sec. shall be allowed between the release of the loading system and reading of its angular movement.

NOTE.—An angle of 30 deg. has been chosen as the standard angle of bend, because experience has shown that with the amount of plastic deformation resulting from this angular movement the test is most sensitive to small differences in temper. In particular cases other angles of bend may be found advantageous.

(*h*) *Test Routine.*—With the specimen in place, the loading system shall be released. The angle between the initial and final positions of the pointer as read from the scale shall be recorded.

(*i*) *Calculation of Energy.*—When it is desired to calculate the energy absorbed by the specimen, the following equation shall be used:

$$E = L R \sin \Theta$$

where E = the energy in centimeter-grams,
L = the unbalanced weight of loading system, in grams,
R = the distance from axis of rotation of weighted loading system to its center of gravity, in centimeters, and
Θ = the angle in degrees between initial and final positions of loading system.

Report

7. The report shall include the following:

(*a*) Identification of specimen,

(*b*) Diameter of specimen,

(*c*) If the specimen has initial curvature, the angle between the plane of curvature and the clamping face of the fixed jaw of the specimen clamp,

(*d*) Machine adjustment and test conditions:
  - (*1*) Weighting used to produce bending,
  - (*2*) Distance from center of gravity of weight to the axis of rotation,
  - (*3*) Radial distance from axis of rotation of loading system to center of contact surface of bending die, and
  - (*4*) Time interval between release of loading system and reading of its angular movement.

(*e*) Test results:
  - (*1*) Angular movement of loading system, and if desired
  - (*2*) Calculated energy absorbed by specimen expressed in centimeter-grams.

TENTATIVE METHOD OF TEST
FOR
TEMPERATURE-RESISTANCE CONSTANTS OF SHEET MATERIALS FOR SHUNTS AND PRECISION RESISTORS[1]

A.S.T.M. Designation: B 114 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method of test provides a procedure for determining the change of resistance with temperature of sheet materials used for shunts and precision resistors for electrical apparatus. It is applicable to materials normally used in the temperature range of from 0 to 80 C.

Test Specimen

2. The test specimen shall be of such dimensions that its electrical resistance can be measured to the required accuracy.

NOTE.—Measurements are simplified if the specimen has a resistance of 0.01 ohm or more. The specimen may be bent in the form of a "U" to facilitate handling.

Terminals

3. (*a*) A current terminal shall be attached to each end of the specimen. These terminals shall be either soldered or clamped in such a manner that there will be no change of current distribution in the specimen during the test.

(*b*) Potential terminals, one at each end, shall be located at a distance not less than two times the width of the specimen from the current terminals. These terminals shall be attached at the center of the width of the specimen either by soldering to ears cut out of the specimen (Note) as shown in Fig. 1 or by clamps, each of which presses a single sharp point into the material.

NOTE.—The ears shall be cut so that they are about $\frac{1}{2}$ in. in length and $\frac{1}{8}$ in. in width. The cut shall be clean and free from slivers at the junction of the ear and the specimen. Before cutting the ears it is desirable to drill two small holes with a sharp drill where the ear will be joined to the specimen.

Preliminary Treatment for Manganin Samples

4. (*a*) In the case of manganin materials, after all the mechanical work has been finished, the specimen shall be given one heat treatment of 48 hr. at 140 ± 5.0 C. and then cooled to room temperature.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys.

(*b*) The specimen shall then be given a dip in a nitric acid solution (50 per cent) to remove the copper film (which can be judged by the color of the specimen) and then thoroughly scrubbed in running water.

Apparatus

5. The apparatus for making the test shall consist of one or more baths for maintaining the desired temperature, thermometers for measuring the temperature, and means for measuring the resistance of the specimen.

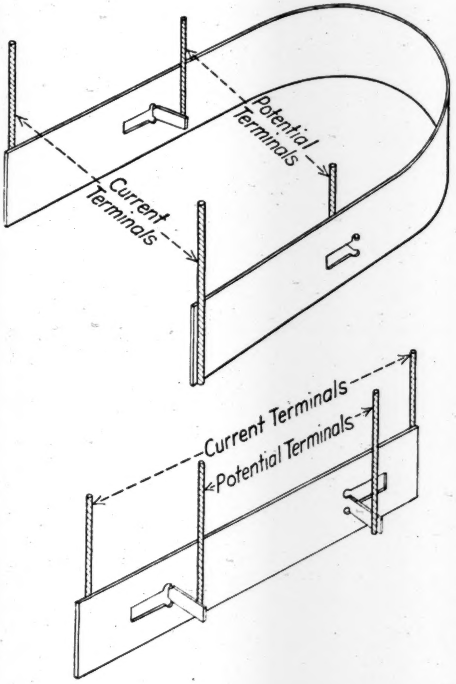

FIG. 1.—Test Specimen Showing Terminal Connections.

Baths

6. Each bath shall consist of chemically-neutral oil. The oil shall be of such quantity and so well stirred that the temperature in the region which is occupied by the specimen and the thermometer shall be uniform within 0.2 C. for any temperature between 0 and 80 C.

Temperature Measurement

7. The temperature shall be measured with a laboratory type of mercurial or resistance thermometer. The thermometer shall have sufficient sensitivity to indicate temperature changes of 0.1 deg. Cent. It shall

be sufficiently accurate to measure temperature differences to 0.2 deg. Cent. in the range from 0 to 80 C.

Resistance Measurements

8. (*a*) The change of resistance of the specimen shall be measured by apparatus capable of determining such changes to 0.001 per cent of the resistance of the specimen. A Kelvin double bridge is suitable for this purpose (see Appendix).

(*b*) The temperature of the measuring apparatus shall not change during the test by an amount sufficient to introduce appreciable errors in the results. With apparatus of good quality a change of 1 C. in its temperature is allowable.

(*c*) The test current shall not be of such magnitude as to produce an appreciable change in resistance of the specimen or measuring apparatus due to heating effect.

NOTE.—The dimensions of the specimen should be such that the power dissipated shall not exceed 0.02 w. per sq. in. (0.003 w. per sq. cm.) of exposed surface. To determine experimentally that the normal test current is not too large, the specimen may be immersed in a bath having a temperature at which it has been found that the sheet has a relatively large change in resistance with temperature. The test current should be applied and maintained until the resistance of the specimen has become constant. The current should then be increased by 40 per cent and maintained at this value until the resistance has again become constant. If the change in resistance is greater than 0.001 per cent the test current is too large and should be reduced until the foregoing limitation is reached.

(*d*) The measurements shall be made in such a way that the effects of thermoelectromotive forces and parasitic currents are avoided. When these effects are small, the resistance of the specimen when measured by a Kelvin bridge may be obtained by either of two methods. In the first method, the galvanometer zero shall be obtained with the galvanometer key open. The bridge shall be balanced both with the direct and reversed connection of the battery, the average value of the two results being the resistance of the specimen. In the second method, the zero of the galvanometer shall be obtained with the galvanometer key closed and the battery key open. A single balance of the bridge is then sufficient to obtain the resistance of the specimen.

Procedure

9. (*a*) The test specimen shall be connected in the measuring circuit and shall be entirely submerged in the oil bath. For a check on the constancy of the specimen, an initial resistance measurement shall be made at room temperature. The temperature of the oil bath shall be raised or the specimen transferred to a bath maintained constant at the highest temperature at which measurements are to be made. When the test specimen has attained a constant resistance, the reading of the measuring device and the temperature of the bath shall be recorded.

(*b*) The temperature of the test specimen shall then be decreased to the next lower temperature either by cooling the bath and maintaining it constant at the next lower temperature or by removing the specimen to another bath maintained at the lower temperature. When the resistance of the specimen has become constant, observations of resistance and temperature shall again be made.

(*c*) In this manner a series of determinations of the change of resistance with temperature shall be made for the desired descending temperature range.

(*d*) Measurements shall be made at a sufficient number of temperatures to determine the characteristics of the material. In order to calculate a resistance-temperature equation three temperatures are required. If an independent check is to be made observations shall be made at at least five temperatures. For plotting a curve six or more observations are generally made.

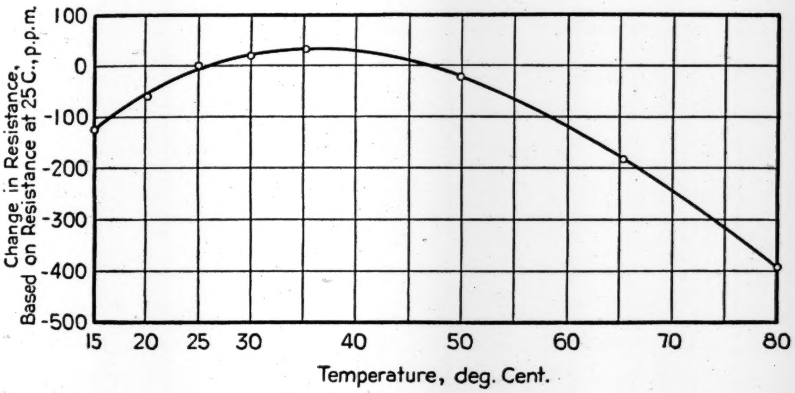

FIG. 2.—Temperature-Resistance Curve of Sheet Manganin Received From John Doe, January, 1937 (see Table I).

(*e*) The temperature of the measuring apparatus shall be noted at frequent intervals during the test of each specimen.

Method of Reporting Results

10. The results shall be reported in one of the following forms (see Table I):

(*a*) The maximum percentage change within the temperature range.

(*b*) A curve, plotted with temperature as abscissas, and the percentage or parts per million change in resistance as ordinates.

(*c*) The constants, α, β, etc., in a resistance-temperature equation may be calculated from the data and recorded as the constants of the temperature-resistance curve.

NOTE:—The resistance-temperature equation and method of calculating the constants are the same as given in the Standard Method of Test for Temperature-Resistance Constants of Alloy Wires for Precision Resistors (A.S.T.M. Designation: B 84) of the American Society for Testing Materials.[1]

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 752.

TABLE I.—ILLUSTRATIVE FORM FOR REPORTING TEST DATA AND CALCULATIONS.

NOTE.—The following table, with test values inserted for purpose of illustration, is only a suggested form for recording test data and calculations.

Apparatus............Kelvin bridge for comparing the specimen with standard resistor.
Standard resistor......No. 38472, 0.0100000 ohm, made by Richard Roe.
Ratio coils............A = 1000. B = 1000.

Material..............Manganin, Specimen No. 1 from shipment received January, 1937.
Maker................John Doe.
Size..................0.020 by 3 by 72 in.; approximate resistance of specimen 0.01 ohm.

RECORD OF TEST

Time	Temperature, deg. cent.			Bridge Reading			Resistance of Specimen, ohm	Change in Resistance,[a] p. p. m.
	Room	Standard	Specimen	Plus	Minus	Average		
10:00..................	25.0	25.0	25.0	1000.00	1000.02	1000.01	0.0100001[b]	.....
10:30..................	25.0	25.0	80.2	999.60	999.62	999.61	0.0099961	−390
10:45..................	25.0	25.0	65.3	999.81	999.82	999.82	0.0099982	−180
11:00..................	25.0	25.0	49.8	999.98	999.98	999.98	0.0099998	−20
11:15..................	25.1	25.1	35.1	1000.02	1000.04	1000.03	0.0100003	+30
11:30..................	25.1	25.1	30.0	1000.02	1000.02	1000.02	0.0100002	+20
11:45..................	25.2	25.1	25.0	1000.00	999.99	1000.00	0.0100000	0
12:00..................	25.4	25.1	20.2	999.94	999.95	999.94	0.0099994	−60
12:15..................	25.5	25.2	15.0	999.88	999.88	999.88	0.0099988	−120
1:00..................	25.5	25.3	25.1	1000.00	1000.00	1000.00	0.0100000[b]	.....

[a] Change in resistance based on the resistance at 25 C.

[b] These values are used for checking the stability only. If these values show a change of more than 0.002 per cent, then the preliminary treatment prescribed in Section 4 should be repeated. If after this treatment the values show still further change the vendor should be consulted.

Results:

(*1*) Maximum change in resistance, 420 p. p. m., or 0.042 per cent between 35 and 80 C.
(*2*) Curve (see Fig. 2).
(*3*) Calculation of the constants in the resistance-temperature equation:

ORIGINAL

TEMPERATURE, DEG. CENT.	$\Delta R_t \times 10^{-6}$
25..................	0
15..................	− 120
65..................	− 180

$\Delta t = 10$
$K = 4$
$\alpha = +8.7 \times 10^{-6}$
$\beta = -0.33 \times 10^{-6}$

SUPPLEMENTARY

TEMPERATURE, DEG. CENT.	$\Delta R_t \times 10^{-6}$
25..................	0
20..................	− 60
80..................	− 390

$\Delta t = 5$
$K = 11$
$\alpha = +10.4 \times 10^{-6}$
$\beta = -0.32 \times 10^{-6}$

Average $\alpha = +9.6 \times 10^{-6}$
Average $\beta = -0.33 \times 10^{-6}$

Temperature for maximum resistance $= 25 \text{ C.} - \frac{\alpha}{2\beta} = 25 \text{ C.} - \frac{+9.6}{-0.66} = 39.5 \text{ C.}$

Report

11. The report shall include the following:

(*a*) Identification of specimen,

(*b*) Description of material,

(*c*) Total length of specimen,

(*d*) Approximate resistance and distance between potential terminals,

(*e*) Tabular list of resistances or changes in resistance and temperatures in the order taken,

(*f*) Temperature of measuring apparatus and room at start and finish of the test,

(*g*) The temperature of the specimen at which the change of resistance with temperature is zero, if such occurs within the measured range, and

(*h*) The results expressed in one of the forms given in Section 10.

APPENDIX

THE KELVIN DOUBLE BRIDGE

There are several methods by which the Kelvin bridge may be so balanced that the ratio of the unknown to the standard is the same as the ratio of the two arms. The following method is indicated as being a satisfactory method for specimens having a resistance of 0.01 ohm or more.

It is important that all the resistances except the ratio arms shall be kept as small as possible. In particular r_1, r_2, r_3, and r_4 should be less than 0.01 of the resistance of the ratio arms. The resistance of the connection between X and N should be less than the sum of X and N.

The balance is made by a series of approximations. The two sets of ratio arms, A, B and a, b, should have the same values, and whenever adjusted the two should be adjusted simultaneously so that at all times $A = a$ and $B = b$. The bridge must be adjusted under three different conditions. These adjustments may be made in the following order:

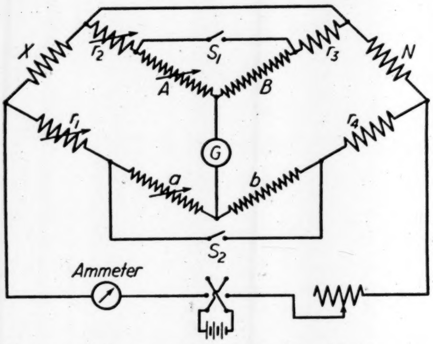

FIG. 3.—Diagram of Kelvin Double Bridge.

1. With switches S_1 and S_2 open, balance with double ratio dials, A and a,
2. With S_1 open and S_2 closed, balance by adjusting the balancing resistor r_1, and
3. With S_2 open and S_1 closed, adjust r_2.

This cycle must be repeated until no change in the double ratio dials is required at the end of the cycle over that at the beginning.

When the above balances have been obtained the resistance X of the unknown is represented by the equation:

$$X = N\frac{a}{b}$$

However, to determine the effect of temperature it is not necessary that the value of N shall be known, for if b and N are kept constant and a changed as the resistance of X is changed because of change in temperature, then the percentage change in X is the same as the percentage change in a.

In making the balance the resistors r_1 and r_2 are adjusted although these do not in any way enter into the final equation. Hence, any simple type of adjustable resistor is entirely satisfactory. In practice many laboratories use merely a short piece of copper wire, one terminal of which is held under a binding post. The resistance adjustment is made by loosening the binding post and sliding the copper wire as required to increase or decrease the resistance.

TENTATIVE SPECIFICATIONS

FOR

MASONRY CEMENT[1]

A.S.T.M. Designation: C 91 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1938.

Scope

1. These specifications cover cement to be used in conjunction with sand in the making of mortar for laying units of masonry construction.

SPECIFICATIONS

Time of Setting

2. Neat cement paste mixed to normal consistency shall not develop initial set in less than 60 min. as determined by the Gillmore needle. Final set shall be attained within 48 hr.

Soundness

3. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Compressive Strength

4. The average compressive strength of not less than three 2-in. cubes, made, stored, and tested in accordance with Sections 19 to 24, shall be not less than 350 lb. per sq. in. at the age of 7 days. The average strength at 28 days shall be not less than 600 lb. per sq. in.

Water Retention

5. Cement mortar after suction for 60 sec. shall have a flow greater than 65 per cent of that immediately after mixing when tested in accordance with the procedure described in Section 25.

Packaging and Marking

6. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer and the net weight plainly marked thereon. All packages shall be in good condition at the time of inspection. Packages varying more than 5 per cent from the weight marked thereon

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-1 on Cement.

may be rejected, and if the average weight of packages in any shipment as shown by weighing 50 packages taken at random is less than the weight marked thereon, the entire lot represented may be rejected.

Storage

7. The cement shall be stored in a suitable weathertight building which will protect it from dampness, and in such a manner as to permit safe and easy access for proper inspection and identification of each lot.

Inspection

8. Every facility shall be provided the purchaser for the necessary inspection and sampling.

Rejection

9. The cement shall be rejected if it fails to meet any of the requirements of these specifications. Cement remaining in storage prior to shipment for a period greater than 6 months after test shall be retested and shall be rejected if it fails to meet any of the requirements of these specifications.

SAMPLING AND METHODS OF TESTING

Size and Number of Samples

10. Each sample of cement selected for purpose of tests shall weigh at least 5 lb. and shall represent not more than 300 bbl. If only one sample is taken it shall weigh at least 10 lb.

Shipment of Samples

11. Samples shall be shipped and stored in airtight, moistureproof containers.

Methods of Testing

12. All test procedures not otherwise specified in Sections 13 to 25 shall be in accordance with the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials.[1]

Temperature

13. temperature of the room and dry materials shall be maintained at not less than 20 C. (68 F.) and not more than 27.5 C. (81.5 F.). The temperature of the mixing water, moist closet, and water in the briquet storage tank shall not vary from 21 C. (70 F.) more than 1.7 C. (3 F.).

Preparation of Samples

14. The sample of cement shall be given a preliminary sieving by being passed through a No. 20 sieve in order to thoroughly mix the sample, break up lumps, and remove foreign materials.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

Mixing

15. (*a*) *Pastes.*—A 500-g. portion of the cement shall be placed in the form of a crater on a plane nonabsorbing plate. About one-half of the necessary mixing water shall be poured into the crater, the cement mixed into the water with the finger tips until all the water is taken up by the cement, the remainder of the water added, and the paste then mixed with the fingers until all the water is absorbed. The mixing operation shall then be completed by continuously and vigorously squeezing and kneading the paste with the hands for at least 3 min. During the operation of mixing, the hands shall be protected by rubber gloves.

(*b*) *Mortars.*—The mortars shall be mixed in a nonabsorbent bowl of about 1-gal. capacity. A measured quantity of water shall be poured into the bowl which has previously been wiped with a damp cloth. A 500-g. portion of the cement shall then be added and stirred into the water with the fingers of one hand until all the cement is wetted. Approximately 800 g. of sand shall then be added and the stirring continued for 30 sec. The remainder of 1500 g. of sand shall then be added and the mortar mixed for 75 sec. by vigorous and continued stirring, squeezing and kneading with one hand. The mortar shall then be allowed to stand for 60 sec. and then mixed for another 60 sec. During the operation of mixing the hands shall be protected by rubber gloves.

Normal Consistency

16. Normal consistency shall be determined by the Vicat apparatus in accordance with Sections 29 and 30 of Standard Methods C 77.[1]

Time of Setting Test

17. The time of setting shall be determined by the Gillmore needle method in accordance with Sections 39 and 40 of Standard Methods C 77.[1] The cement pats shall be stored during the test in a damp closet maintained at a relative humidity of 90 per cent or more.

Soundness Test

18. Pats of neat cement, made and tested in accordance with Sections 33 to 35 of Standard Methods C 77[1] shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegration. If pats have not attained final set at the end of 24 hr., they shall remain in the moist cabinet for 48 hr. before being subjected to the steam test.

Compressive Strength Test

19. *Molds* (*a*).—The Compression test specimens shall be 2-in. cubes. Molds for the 2-in. cube test specimens shall be tight fitting. The parts of the molds when assembled shall be positively held together. The molds

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

shall be made of hard metal not attacked by the cement mortar. For new molds the Rockwell hardness number of the metal shall be not less than B55 (the Brinell hardness number not less than 95). There shall be sufficient material in the sides of the molds to prevent spreading or warping.

(*b*) The interior faces of the molds shall be true plane surfaces with a tolerance of plus or minus 0.001 in. for new molds of plus or minus 0.002 in. for molds in use.

(*c*) The distances between opposite faces of the molds shall be 2 ± 0.005 in. for new molds, or 2 ± 0.01 in. for molds in use. The height of the molds, measured separately for each cube compartment, shall be 2 in. with tolerance of plus 0.01 in. and minus 0.005 in. for new molds; or plus 0.01 in. and minus 0.015 in. for molds in use.

(*d*) The angle between adjacent interior faces, and between interior faces and top and bottom planes of the mold shall be 90 ± 0.5 deg.

(*e*) Molds shall be oiled with a mineral oil before using.

20. (*a*) *Proportions for Standard Mortar.*—The mortar shall consist of 1 part cement to 3 parts by weight of standard Ottawa sand (Nos. 20 to 30 sieve). The Ottawa sand shall conform to the requirements described in Sections 42 to 44 of Standard Methods C 77.[1]

(*b*) *Preparation of Standard Mortar.*—The mortar shall be mixed with a measured quantity of water in accordance with the procedure described in Section 15 (*b*). The top of the flow table (Paragraph (*c*)) shall be carefully wiped dry and the flow mold placed at the center and filled with mortar. In filling the mold the mortar shall not be rammed, but gently smoothed off level with the top of the mold by aid of a trowel and the mold then removed. Immediately, the table shall be dropped through a height of $\frac{1}{2}$ in., 25 times in 15 sec. The flow is the resulting increase in diameter of the mortar mass, expressed as a percentage of the original diameter. The mortar shall be of standard consistency when the flow is 65 to 80 per cent. Trial mortars shall be made with varying percentages of water until the standard consistency is obtained. Each trial shall be made with fresh mortar. The quantity of water shall be expressed as a percentage of the weight of the combined dry materials.

(*c*) *Flow Table.*—The flow table apparatus consists of a rigid frame with a flat circular top, so mounted on a vertical shaft that it can be raised and dropped through a fixed height of $\frac{1}{2}$ in. ($\pm \frac{1}{32}$ in.) by means of a rotated cam. The top shall be of noncorrodible metal 10 in. in diameter and with the attached shaft shall weigh 9 lb. ± 1 oz. The frame shall be attached rigidly to a concrete pedestal, which in turn shall be attached rigidly to the floor. The concrete pedestal shall be at least 8 in. in diameter and 25 in. in height and shall weigh at least 100 lb. The mold shall be of a noncorrodible material, 4 in. in inside diameter at the base, $2\frac{3}{4}$ in. at the top and 2 in. high.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

21. *Molding of Test Cubes.*—Immediately after mixing the standard mortar in accordance with the procedure described in Sections 15 and 20, the mortar shall be placed in the cube molds which shall rest on plane nonabsorbent plates. The molds shall be filled heaping full without compacting. Then the mortar shall be gently worked into the molds with the thumbs, using only sufficient effort to insure uniform filling of the molds. Additional mortar shall be heaped above the molds and smoothed-off with a trowel. The molds and plates shall then be turned over upon plane nonabsorbent plates oiled with mineral oil, the first plates removed, and the operation of heaping, thumbing and smoothing-off repeated. No ramming or tamping shall be used, nor any trowelling in excess of that required to smooth-off the specimens.

22. *Storage of Test Cubes.*—All test specimens, immediately after molding, shall be kept in the molds on plane plates in a damp closet, maintained at a relative humidity of 90 per cent or more for from 48 to 52 hr. in such a manner that the upper surfaces shall be exposed to the moist air. The cubes shall then be removed from the molds and placed in the damp closet for 5 days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of 7 days the cubes for the 28-day tests shall be immersed in clean running water in storage tanks of noncorrodible materials.

23. *Testing of Cubes* (*a*).—The testing machine for determination of the compressive strength may be of either the hydraulic or the screw-type with sufficient opening between the upper bearing surface and the lower bearing surface of the machine to permit the use of verifying apparatus. The load applied to the test specimen shall be indicated with an accuracy of plus or minus 1.0 per cent.

(*b*) The upper bearing shall be a spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface of the block in contact with the specimen. The block shall be closely held in its spherical seat, but shall be free to turn in any direction. The diagonal or diameter of the bearing surface shall be only slightly greater than the diagonal of the face of the 2-in. cube in order to facilitate accurate centering of the specimen. A hardened metal bearing block shall be used beneath the specimen to minimize wear of the lower plate of the machine. The bearing block surface intended for contact with the specimen should have a hardness not less than Rockwell number C60 (Brinell number 620). These surfaces shall not depart from plane surfaces by more than 0.0005 in. when the blocks are new and shall be maintained within a tolerance of 0.001 in.

(*c*) Testing of the cube specimens shall be carried out immediately upon their removal from the moist closet for 7-day specimens, and from storage water for all other specimens. If more than one specimen at a time is removed from the storage water for testing, these cubes shall be placed in a pan of water of sufficient depth to completely immerse each cube until its removal for testing. The load shall be applied to the faces of the cubes that were in contact with the true plane surfaces of the mold. These faces shall be checked by application of an accurate straight edge. If appreciable curvature is present, the face or faces shall be ground to a plane surface before loading, or the specimens shall be discarded.

(*d*) Loose sand grains or incrustations shall be removed from the contact faces and cubes shall then be carefully placed in the testing machine below the center of the upper bearing block. No cushioning or bedding materials shall be used. The loading up to 25 per cent of the expected maximum load may be applied at any convenient rate, after which the specimens shall be loaded continuously to failure at a rate or rates which shall at no time be less than 1000 nor more than 6000 lb. per sq. in. per min.

24. *Calculations of Compressive Strength.*—The total maximum load indicated by the testing machine shall be recorded, and the compressive strength calculated in pounds per square inch from the cross-sectional area of the cube tested. Cubes that are manifestly faulty or that give strengths differing by more than 10 per cent from the average value of all test specimens made from the same sample and tested at the same period shall not be considered in determining the compressive strength.

Water Retention Test

25. (*a*) *Apparatus.*—For the water retention test an apparatus essentially the same as that shown in Fig. 1 shall be used. This apparatus consists of a water aspirator controlled by a mercury column relief and connected by way of a three-way stop cock to a funnel upon which rests a perforated dish. A mercury manometer connected as shown in Fig. 1 indicates the vacuum. A rubber gasket shall be sealed to the top of the funnel and shall be kept wet during a test to insure a seal between the funnel and dish. The perforated dish shall be made of nonabsorbent material. Hardened filter paper equivalent to Carl Schleicher and Schull filter paper No. 575 shall be used. It shall be of such diameter that it will lie flat and completely cover the bottom of the dish.

(*b*) *Method.*—The mortar shall be mixed to a flow of from 100 to 115 per cent in accordance with the procedure described in Section 20. Immediately after making the flow test, the mortar on the flow table shall be remixed with that remaining in the mixing bowl for 30 sec. Immediately after remixing, the mortar shall be uniformly distributed without compacting over the sheet of dampened filter paper in the perforated dish and the surface levelled-off flush with the rim of the dish by drawing a straight edge across the dish with a slightly sawing motion. The dish shall then be seated on the wetted gasket, and with the mercury column set at 2 in., the stopcock shall be turned to apply the vacuum to the funnel. After suction for 60 sec., the stopcock shall be quickly turned to expose the funnel to atmospheric pressure. The contents of the dish shall then be immediately removed by means of a putty knife or square-end spatula and placed in the mold on the flow table. As each portion of mortar is placed in the mold it shall be well puddled with glove-covered fingers.

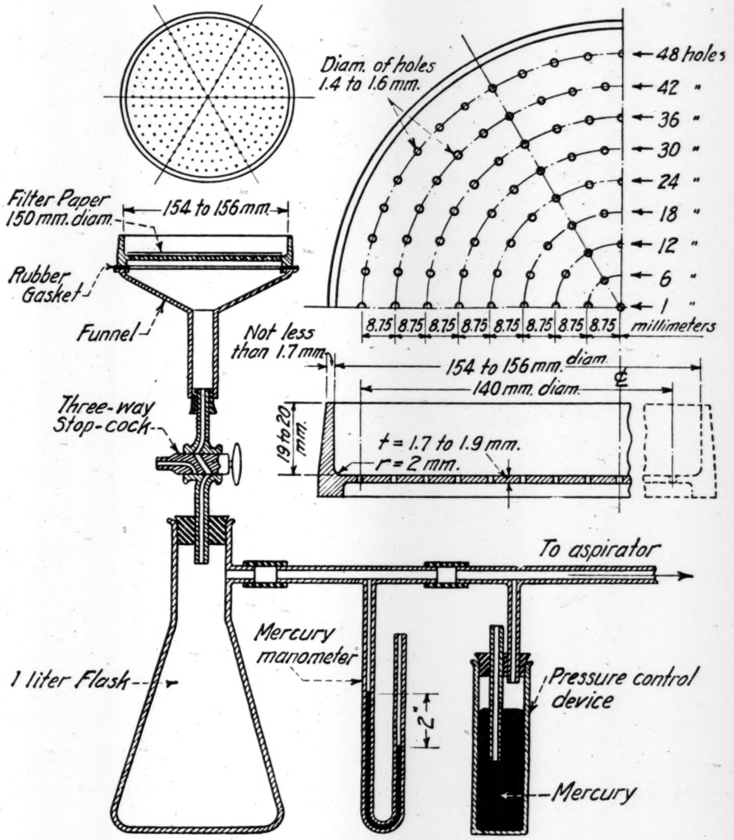
Diam. of holes 1.4 to 1.6 mm.
48 holes
42 "
36 "
30 "
24 "
18 "
12 "
6 "
1 "
8.75
8.75
8.75
8.75
8.75
8.75
8.75
8.75
millimeters
Filter Paper 150 mm. diam.
154 to 156 mm.
Rubber Gasket
Funnel
Not less than 1.7 mm.
154 to 156 mm. diam.
140 mm. diam.
℄
19 to 20 mm.
t = 1.7 to 1.9 mm.
r = 2 mm.
Three-way Stop-cock
To aspirator
Mercury manometer
2"
1 liter Flask
Pressure control device
Mercury

FIG. 1.—Apparatus Assembly for the Water Retention Test.

When the mold is filled, the mortar shall be smoothed-off level with the top of the mold, using the edge of trowel, and the flow determined as previously. The entire operation shall be carried out without interruption and as quickly as possible and shall not require more than 7 min. for completion, starting from the completion of the mixing of the mortar for the first flow determination. Both flow determinations shall be made in accordance with the procedure described in Section 20 (*b*), special care being taken to fill the mold uniformly when obtaining the flow after suction.

TENTATIVE METHODS

OF

CHEMICAL ANALYSIS OF PORTLAND CEMENT[1]

A.S.T.M. Designation: C 114 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.[2]

PHOSPHORUS

Special Solutions Required

1. (*a*) *Ammonium Molybdate.*—Dissolve 100 g. of molybdic acid (85 per cent MoO_3) in a mixture of 400 ml. of water and 100 ml. of NH_4OH (sp. gr. 0.90) and cool the solution to room temperature. While stirring constantly, pour this solution very slowly into a cooled mixture of 500 ml. of water and 400 ml. of HNO_3 (sp. gr. 1.42). No permanent precipitate should form, which does not redissolve with stirring. Add 1 drop of a saturated solution of sodium-ammonium phosphate ($NaNH_4HPO_4$) to the solution, shake it thoroughly, and allow it to stand at least 24 hr. before use. Filter portions of the solution as needed.

(*b*) *Magnesia Mixture.*—Dissolve 50 g. of $MgCl_2 \cdot 6H_2O$ and 100 g. of NH_4Cl in 500 ml. of water. Make the solution slightly alkaline with NH_4OH and allow it to stand at least 12 hr. Filter the solution, acidify it with HCl and dilute to 1 liter.

Procedure

2. (*a*) Weigh a 1 to 3-g. sample of cement (Note) into a 250-ml. beaker. Treat the cement with 50 to 75 ml. of water and then with 10 to 15 ml. of HNO_3 (sp. gr. 1.42). Boil the mixture until the solution is as complete as possible. If the cement contains an appreciable amount of manganese as shown by the presence of a red or brown residue, add a few milliliters of a potassium nitrite solution (5 per cent) to aid in the solution. Boil the solution until all nitrous fumes are completely expelled, taking care not to allow the volume of the solution to become so small as to cause the precipitation of gelatinous silica. Filter the solution into a 500-ml. Erlenmeyer flask and wash the residue. The volume of the solution should now be about 150 ml.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee C-1 on Cement.

[2] These methods when adopted as standard are intended to be included with the procedures for chemical analysis appearing in Sections 8 to 17 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77), see 1937 and 1938 Supplements to Book of A.S.T.M. Standards.

NOTE.—The amount of sample and reagents used depend on the content of phosphorus in the cement. The minimum requirements are sufficient if the cement contains 0.5 per cent P_2O_5 or more. The maximum amounts are required if the content of P_2O_5 is 0.1 per cent or less.

(*b*) Add 10 g. of ammonium nitrate to the solution and heat until the salt is dissolved. Heat the solution to 85 C. and add 50 to 100 ml. of the solution of ammonium molybdate. Stopper the flask and shake it vigorously for 5 min., then set it aside for 30 min. Filter the precipitate, rinsing the flask five times and washing the filter paper eight times with a cold solution of potassium nitrate (1 per cent).

(*c*) Put the original flask under the funnel containing the precipitate. Pour 25 ml. of diluted NH_4OH (1:4) over the precipitate and around the upper edges of the filter paper until the precipitate is entirely dissolved. Wash the paper three times with cold water, twice with diluted HCl (1:1), and finally three times with cold water. Acidify the solution with HCl and add to it 4 or 5 drops of a saturated solution of citric acid to hold traces of iron, if any, in solution. Cool the solution to room temperature and transfer it to a 400-ml. beaker. The volume of the solution should now be about 150 ml.

(*d*) To the solution add 25 ml. of magnesia mixture, and then while stirring constantly add drop by drop 50 ml. of NH_4OH (sp. gr. 0.90) at such a rate that 5 min. are required for the addition. Allow the mixture to stand 4 hr. or longer. Filter the precipitate and wash it a few times with diluted NH_4OH (1:20). Dissolve the precipitate into the original beaker by pouring 25 ml. of diluted HCl (1:1) on the precipitate. Wash the filter paper thoroughly with diluted HCl (1:20). With the washings and water, dilute the solution to 50 to 100 ml. and add to it 1 to 2 ml. of magnesia mixture. While stirring constantly, add NH_4OH slowly to the solution as before. Allow the mixture to stand 2 hr. or longer. Filter the precipitate, scrub and rinse the beaker, and wash the precipitate ten times with diluted NH_4OH (1:20). Ignite the precipitate in a weighed crucible at 1100 to 1200 C. to constant weight. Multiply the weight of the magnesium pyrophosphate ($Mg_2P_2O_7$) by 0.6379 to get the weight of the phosphorus in the sample as P_2O_5.

(*e*) *Blank Correction.*—Make a blank determination, using the same procedure as outlined above, and using approximately the same amount of reagents. Correct the weight of magnesium pyrophosphate ($Mg_2P_2O_7$) accordingly.

(*f*) If a determination of phosphorus is required, the weight of the ferric oxide and alumina ($Al_2O_3 + Fe_2O_3$) as obtained by the method described in Section 12 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materals[1] shall be corrected for the amount of the P_2O_5 found.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

MANGANESE

Method A

Special Solutions Required

3. (*a*) *Standard Sodium Arsenite Solution.*—Dissolve in 100 ml. of water 3.0 g. of Na_2CO_3 and then 0.9008 g. of As_2O_3, heating the mixture until the solution is as complete as possible. If the solution is not clear or contains a residue, filter the solution. Cool it to room temperature, transfer it to a volumetric flask, and dilute it to 1 liter. Each milliliter of this solution is approximately equivalent to 0.0003 g. of Mn_2O_3.

(*b*) Dissolve 0.58 g. of $KMnO_4$ in 1 liter of water and standardize it against 0.0300 g. of sodium oxalate oxidimetric standard furnished by the National Bureau of Standards (Standard Sample No. 40) according to the directions furnished with the sodium oxalate. Put 30.0 ml. of the $KMnO_4$ solution in a 250-ml. Erlenmeyer flask. Add 60 ml. of diluted HNO_3 (1:4) and 10 ml. of a potassium nitrite solution (5 per cent) to the flask. Boil the solution until the nitrous acid is completely expelled. Cool the solution and add sodium bismuthate and finish by titrating with the standard solution of As_2O_3 in the manner described below for the determination of manganese in cement.

(*c*) The value of the standard solution of As_2O_3 per milliliter in terms of grams of Mn_2O_3 is:

$$\frac{0.03 \times 0.236 \times 30}{a \times b}$$

where a = the number of milliliters of the solution of $KMnO_4$ required by 0.0300 g. of $Na_2C_2O_4$, and

b = the number of milliliters of the standard solution of As_2O_3 required by 30.0 ml. of the solution of $KMnO_4$.

Procedure

4. (*a*) Weigh a 1.0 to 3.0-g. sample of cement (Note 1) into a 250-ml. beaker and treat it with 5 to 10 ml. of water and then with 60 to 75 ml. of diluted HNO_3 (1:4). Boil the mixture until the solution is as complete as possible. Add 10 ml. of a sodium nitrite solution (5 per cent) to the solution and boil it until the nitrous acid is completely expelled (Note 2), taking care not to allow the volume of the solution to become so small as to cause the precipitation of gelatinous silica. There may be some separated silica which may be ignored; but if there is still a red or brown residue, use more solution of sodium nitrite to effect a complete decomposition and then boil again to expel the nitrous acid. Filter the solution into a 250-ml. Erlenmeyer flask and wash the filter paper with water.

NOTE 1.—The amount of cement taken for analysis depends on the content of manganese, varying from 1 g. for about 1 per cent of Mn_2O_3 to 3 g. for 0.25 per cent or less of Mn_2O_3.

NOTE 2.—When sodium nitrite is added, the expulsion of nitrous acid by boiling must be complete. If any nitrous acid remains in the solution, it will react with the added sodium bismuthate and decrease its oxidizing value. If there is any manganese in the cement, the first small quantity of sodium bismuthate should bring out a purple color.

(*b*) The solution should have a volume of 100 to 125 ml. Cool it to room temperature. To the solution add a total of 0.5 g. of sodium bismuthate in small quantities, with intermittent shaking. After the addition is completed, shake the solution occasionally for 5 min. and then add to it 50 ml. of cool diluted HNO_3 (1:33) which has been previously boiled to expel nitrous acid. Filter the solution through a pad of ignited asbestos in a Gooch crucible or a carbon or fritted-glass filter with the aid of suction. Wash the residue four times with the cool diluted HNO_3 (1:33). Titrate the filtrate immediately with the standard solution of As_2O_3. The endpoint is reached when a yellow color is obtained free of brown or purple tints and it does not change upon further addition of As_2O_3. Calculate the manganese in the cement as Mn_2O_3.

(*c*) *Blank Correction.*—Make a blank determination, using the same procedure as outlined above and using approximately the same amounts of reagents. Correct the titration results accordingly.

(*d*) If a determination of manganese is required in addition to a determination of magnesium by Section 16 of Standard Method C 77,[1] manganese shall be eliminated from the combined filtrates obtained in the alumina and ferric oxide determination before calcium oxide is precipitated (Section 15 of Standard Method C 77)[1] in the following manner:

Acidify the combined filtrates with HCl and evaporate them to a volume of about 100 ml. Add 40 ml. of saturated bromine water to the hot solution and immediately add NH_4OH until the solution is distinctly alkaline. Boil the solution for 5 min. or more, making certain that the solution is at all times distinctly alkaline. Allow the precipitate to settle, filter and wash with hot water. Discard the precipitate. Acidify the filtrate with HCl and boil until all the bromine is expelled. Make the solution alkaline with NH_4OH and proceed in accordance with Section 15 of Standard Method C 77.[1]

Method B[2]

Special Solutions Required

5. (*a*) *Standard Potassium Permanganate Solution.*—Dissolve 5.63 g. of $KMnO_4$ in 1 liter of water and standardize it against 0.7500 g. of sodium oxalate oxidimetric standard furnished by the National Bureau of Standards (Standard Sample No. 40) according to the directions furnished with the sodium oxalate.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.

[2] Alternate method, in case of dispute Method A should be used.

NOTE.—An approximately 0.18 N solution of $KMnO_4$, which is equivalent to about 0.005 g. of CaO per ml. and is generally used in the routine volumetric determination of CaO in cement and raw materials, is convenient to use. 0.005-g. of CaO is equivalent to 0.004224 g. of Mn_2O_3.

(*b*) The value of the standard solution of $KMnO_4$ in terms of grams of Mn_2O_3 per milliliter is:

$$\frac{0.75 \times 0.3534}{a}$$

where a = the number of milliliters of the solution of $KMnO_4$ required by 0.7500 g. of $Na_2C_2O_4$.

Procedure

6. (*a*) Place 2 g. of cement in a 250-ml. beaker and add about 50 ml. of water to the cement. Stir the mixture until it is in suspension and then add about 15 ml. of HCl (sp. gr. 1.19). Heat the mixture gently until the solution is as complete as possible. Add 5 ml. of HNO_3 (sp. gr. 1.42) and 50 ml. of water to the solution and boil it until most of the chlorine has been expelled. If necessary, add hot water to maintain the solution at a volume of about 100 ml. Stop the boiling and add ZnO powder to the solution until the acid is neutralized. Add an excess of 3 to 5 g. of ZnO powder to the solution and boil it for a few minutes.

(*b*) Without filtering and while keeping the solution hot (90 to 100 C.) by intermittent or continuous heating, titrate the solution with the standard solution of $KMnO_4$ until a drop of it gives a permanent pink color (Note). When the end point is approached, add the standard solution dropwise and after each drop, stir the solution and allow the precipitate to settle a little and observe the color of the upper stratum of the solution by looking through the side of the beaker. Calculate the percentage of Mn_2O_3 in the cement by multiplying the burette reading by the value of the standard solution and then by multiplying by 50.

NOTE.—In the case of a cement in which the approximate content of manganic oxide is unknown, a preliminary determination may be made with rapid titration, 0.5 to 1 ml. of the standard solution being added at a time, and without an attempt to keep the solution close to the boiling point.

(*c*) *Blank Correction.*—Make a blank determination, using the same procedure as outlined in Paragraphs (*a*) and (*b*), and using approximately the same amounts of reagents. Correct the titration results accordingly.

POTASSIUM OXIDE AND SODIUM OXIDE[1]

Special Solutions Required

7. (*a*) *Chloroplatinic Acid.*—Dissolve 5 g. of $H_2PtCl_6 \cdot 6H_2O$ in 100 ml. of water.

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[1] The procedure is based on a method developed and used in the laboratories of the Universal Atlas Cement Co., Chicago, Ill.

(*b*) *Gladding Wash.*—Dissolve 100 g. of NH_4Cl in 500 ml. of water, add 5 to 10 g. of pulverized pure K_2PtCl_6 to the solution, and shake the mixture frequently for 6 to 8 hr. Allow the mixture to stand at least 12 hr. and filter. The residue may be used for the preparation of a new supply of the wash.

Procedure

8. (*a*) Weigh a 5-g. sample of finely pulverized cement and mix it with 1 g. of NH_4Cl by grinding the two together in an agate mortar. Add 4 g. of $CaCO_3$ to the mixture and continue the grinding until the mixture is thoroughly mixed. Place about 0.5 cm. of $CaCO_3$ on the bottom of a 40 to 60-ml. platinum crucible, add the above mixture to the crucible, and cover the mixture with about 0.5 cm. of $CaCO_3$. Mount the crucible through a hole in an asbestos board about 0.3 cm. in thickness, so that the crucible projects about 1 cm. above the board. Cover the crucible with a well-fitting cover and set a platinum crucible containing water on it. The purpose of the second crucible is to prevent the loss of alkali by volatilization and the crucible must be kept filled with water through the entire period of ignition. Heat the crucible at a very low temperature at first and gradually raise the temperature within an hour to a bright red heat. At no time should the temperature be raised so fast that white NH_4Cl fumes can be seen issuing from the crucible. Finally, ignite the crucible at 900 to 1000 C. for 1 hr.

(*b*) With the aid of hot water, remove the sintered material from the crucible and let the sinter digest with about 150 ml. of water in a casserole on a water bath for about 4 hr. If there are still lumps in the casserole, break them up with a pestle or glass rod. Allow the mixture to digest on the water bath 4 hr. more, or longer. Boil the mixture for 1 min., allow the residue to settle, and decant the clear solution through a filter paper into a large beaker. Add 30 ml. of water to the casserole, bring the mixture to a boil, allow the residue to settle, and decant the clear filtrate through the same filter paper. Perform three more times this addition of water and decantation. Finally wash the residue into the filter paper, rinse the casserole, and wash the residue once with hot water.

(*c*) Combine the filtrates and washings and evaporate them to about 50 ml. Add 3 or 4 g. of $(NH_4)_2CO_3$ to the solution, and boil it for 1 min. Filter the solution and wash the residue 6 times with a cool solution of $(NH_4)_2CO_3$ (1 per cent) which contains a little NH_4OH. Add 10 ml. of a solution of ammonium oxalate (5 per cent) and 2 or 3 ml. of NH_4OH (sp. gr. 0.90) to the filtrate. Evaporate the solution to about 20 ml., filter into a dish, and wash the residue with hot water. Add 1 ml. of H_2SO_4 (sp. gr. 1.84) to the filtrate and evaporate it to dryness.

(*d*) Ignite the residue in the dish carefully until the excess H_2SO_4 is driven off and then raise the temperature to a dull red heat. Cool the dish, dissolve the residue in 50 ml. of water, and add 2 ml. of a solution of ammonium oxalate (5 per cent) and 2 or 3 ml. of NH_4OH (sp. gr. 0.90) to the solution. Evaporate the solution to about 10 ml., filter the solution into a platinum dish, and wash the residue with hot water. Add 0.5 ml. of H_2SO_4 (sp. gr. 1.84) to the filtrate and evaporate it to dryness. Ignite the residue, gradually raising the temperature to 600 to 700 C. until all the excess H_2SO_4 and ammonium salts are expelled. Cool the dish, dissolve the residue in a small amount of water, evaporate the solution to dryness, ignite the residue at 600 to 700 C. for 15 min., cool it in a dessicator, and weigh. Dissolve the residue in about 20 ml. of hot water, and filter the solution. Wash the filter paper with hot water and put it in the dish. Ignite carefully until the paper is consumed and then continue the ignition at 600 to 700 C. for 10 min. Cool the dish in a dessicator and weigh. The difference between these two weights represents the weight of the alkali as K_2SO_4 and Na_2SO_4.

(*e*) Add 1 to 2 ml. of HCl (sp. gr. 1.19) to the filtrate in a vessel made of glass, silica, or porcelain and evaporate it to about 10 ml. To the solution, add 6 ml. of the solution of chloroplatinic acid for each 0.10 g. of the mixed sulfates and add 3 ml. in excess. Evaporate the solution on a water bath to a thick syrup, carrying this evaporation as far as possible without allowing the solution to go to dryness. The syrupy solution should solidify on cooling. Add 100 ml. of ethyl alcohol (85 per cent) to the solution while stirring thoroughly, and allow the precipitate of potassium chloroplatinate to settle for just 3 hr. Filter the clear liquid through a dried and tared Gooch crucible with a mat of asbestos or a fused-in fritted glass disc. Wash the precipitate five times by decantation with ethyl alcohol (85 per cent) and then rinse the crucible three times with the ethyl alcohol. Wash the precipitate three times by decantation with the Gladding wash, stirring the precipitate thoroughly each time. Transfer the precipitate to the crucible with the Gladding wash, taking care that none remains in the original vessel, and finally wash the crucible and contents six times with ethyl alcohol (85 per cent). Dry the crucible at 105 to 110 C. for at least 3 hr. Cool, and weigh it. The difference between these two weights represents the weight of K_2O as K_2PtCl_6.

(*f*) Calculate the percentages of K_2O and Na_2O in the sample as follows:

Percentage of K_2O = Weight of $K_2PtCl_6 \times 0.1937 \times 20$
Weight of K_2SO_4 = Weight of $K_2PtCl_6 \times 0.3584$
Weight of Na_2SO_4 = Weight of ($K_2SO_4 + Na_2SO_4$) – weight of K_2SO_4
Percentage of Na_2O = Weight of $Na_2SO_4 \times 0.4364 \times 20$

(*g*) Make a blank determination using the same procedure as described in Paragraphs (*a*) to (*e*), and using approximately the same amounts of reagents. Correct accordingly the results previously determined.

WATER-SOLUBLE ALKALI[1]

NOTE.—The determination of water-soluble alkali according to Section 9 should not be considered as a substitute for the determination of total alkali according to Section 8 Moreover, it is not to be assumed that in the procedure of Section 9 all water-soluble alkali is obtained that may be in the cement. A uniform method is essential where there is a specified limit on the content of water-soluble alkali or where several lots of cement are compared on the basis of water-soluble alkali.

Procedure

9. (*a*) Weigh 25 to 150 g. of cement (Note 1) into a large beaker and add 250 ml. of water to the cement while stirring thoroughly (Note 2). Let the mixture stand for 30 min. at room temperature, stir it again, and filter it through a Büchner funnel. Return the residue to the original beaker, rinse the funnel with 150 ml. of water into the beaker, stir the mixture thoroughly, and let it stand 30 min. at room temperature. Again stir the solution and filter it through the Büchner funnel. Return the residue to the beaker and rinse the funnel with 100 ml. of water into the beaker. Stir the mixture thoroughly, and let it stand 30 min. at room temperature. Stir it and filter it as before, discard the residue without washing and follow the procedure described in either Paragraph (*b*) or Paragraph (*c*) (Note 3).

NOTE 1.—The amount of sample taken for analysis depends on the content of water-soluble alkali, varying from 25 g. for 0.5 per cent or more to 150 g. for 0.1 per cent or less

NOTE 2.—As the amount of water-soluble alkali obtained depends on the manner in which it is leached out of cement, it is important that the procedure be followed closely.

NOTE 3.—In most cases the procedure described in Paragraph (*b*) is to be preferred because it is simpler and usually gives all the data necessary.

(*b*) Follow the procedure as described in Section 8 (*c*), (*d*), and (*g*). Calculate as Na_2O the percentage of water-soluble alkali in the sample, as follows:

$$\text{Percentage of } Na_2O = \frac{\text{Weight of sulfates} \times 0.4364 \times 100}{\text{Weight of sample}}$$

(*c*) If it is required that water-soluble alkali be reported as water-soluble K_2O and water-soluble Na_2O, follow the procedure as described in Section 8, starting with Paragraph (*c*) and making the necessary changes in the formulas of Paragraph (*f*) due to the weight of sample taken for analysis. If desired, a measured portion of the combined filtrates may be taken for the steps following the leaching in order to avoid the use of a large amount of chloroplatinic acid.

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[1] The procedure for determining water-soluble alkali as described in Section 9 is identical with Section F-3h of the Federal Specification for Masonry Cement (SS–C–181*a*; May 22, 1936) in regard to leaching of cement. The differences in the treatment of the combined filtrates should not produce an appreciable difference in the results.

TENTATIVE METHOD OF TEST
FOR
FINENESS OF PORTLAND CEMENT BY MEANS OF THE TURBIDIMETER[1]

A.S.T.M. Designation: C 115 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1938.

Scope

1. This method of test covers the Wagner turbidimeter[2] apparatus and procedure for determining the fineness of portland cement as represented by specific surface expressed as total surface area in square centimeters per gram of cement.

APPARATUS

Apparatus

2. The Wagner turbidimeter consists essentially of a source of light of constant intensity adjusted so that approximately parallel rays of light pass through a suspension of the cement to be tested and impinge upon the sensitive plate of a photoelectric cell. The current generated by the cell is measured with a microammeter and the indicated reading is a measure of the turbidity of the suspension. General considerations indicate that turbidity is in turn a measure of the surface area of the suspended sample of cement. The apparatus, illustrated in Figs. 1 and 2, shall consist specifically of the parts described in Sections 3 to 9.

Turbidimeter

3. The turbidimeter shall be mounted in a suitable case and shall include the following features:

(*a*) *Source of Light.*—The source of light (Fig. 2) shall consist of a 3 to 6 candlepower concentrated filament electric lamp operated by a 6-v. storage battery. A parabolic reflector shall be mounted behind the lamp and the lamp focused in such manner that approximately parallel rays of light will pass through the sedimentation tank and will impinge upon the photoelectric cell. The light intensity shall be regulated by means of two rheostats having resistances of approximately 6 and 30 ohms, respectively, and mounted in series with the lamp but in parallel with each other.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-1 on Cement.

[2] This turbidimeter was developed by L. A. Wagner, Research Associate of the Cement Reference Laboratory, National Bureau of Standards, Washington, D. C. A description of the apparatus and mathematical derivations of formulas used are given in the paper, "A Rapid Method for the Determination of the Specific Surface of Portland Cement," by L. A. Wagner, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 553 (1933).

(*b*) *Water Cell.*—The light shall pass through a water cell before entering the sedimentation tank in order that radiant heat from the beam shall be absorbed. The cell shall consist of 3-in. diameter brass tubing, 4 in. in length with glass windows cemented in the ends with a suitable sealing material. A stoppered hole shall provide for filling with distilled water. The cell shall be so arranged that all rays of light entering the sedimentation tank shall first pass through the water.

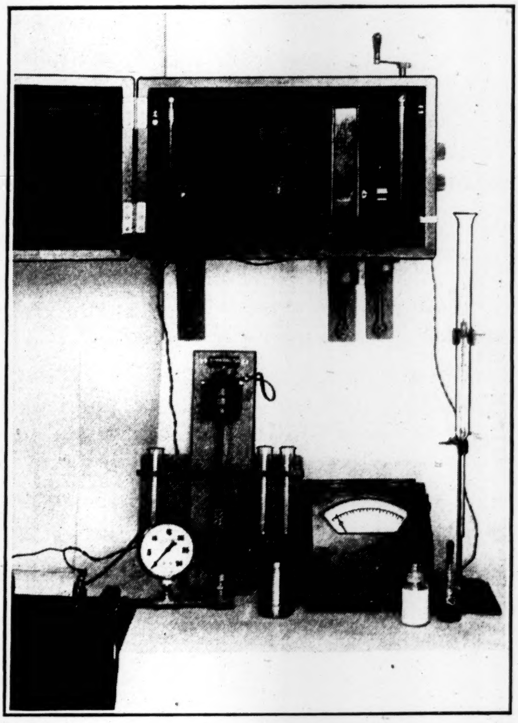

FIG. 1.—Photographic Assembly of Turbidimeter Fineness Test Apparatus.

(*c*) *Retarding Filter.*—A colored glass shall be provided which will reduce the intensity of light from that corresponding to 100 microamperes to a reading of 20 to 30 microamperes. An Eastman filter No. 35D has been found suitable.

(*d*) *Sedimentation Tank.*—The sedimentation tank shall be constructed of $\frac{3}{16}$-in. plate glass cemented together to form a rectangular tank having

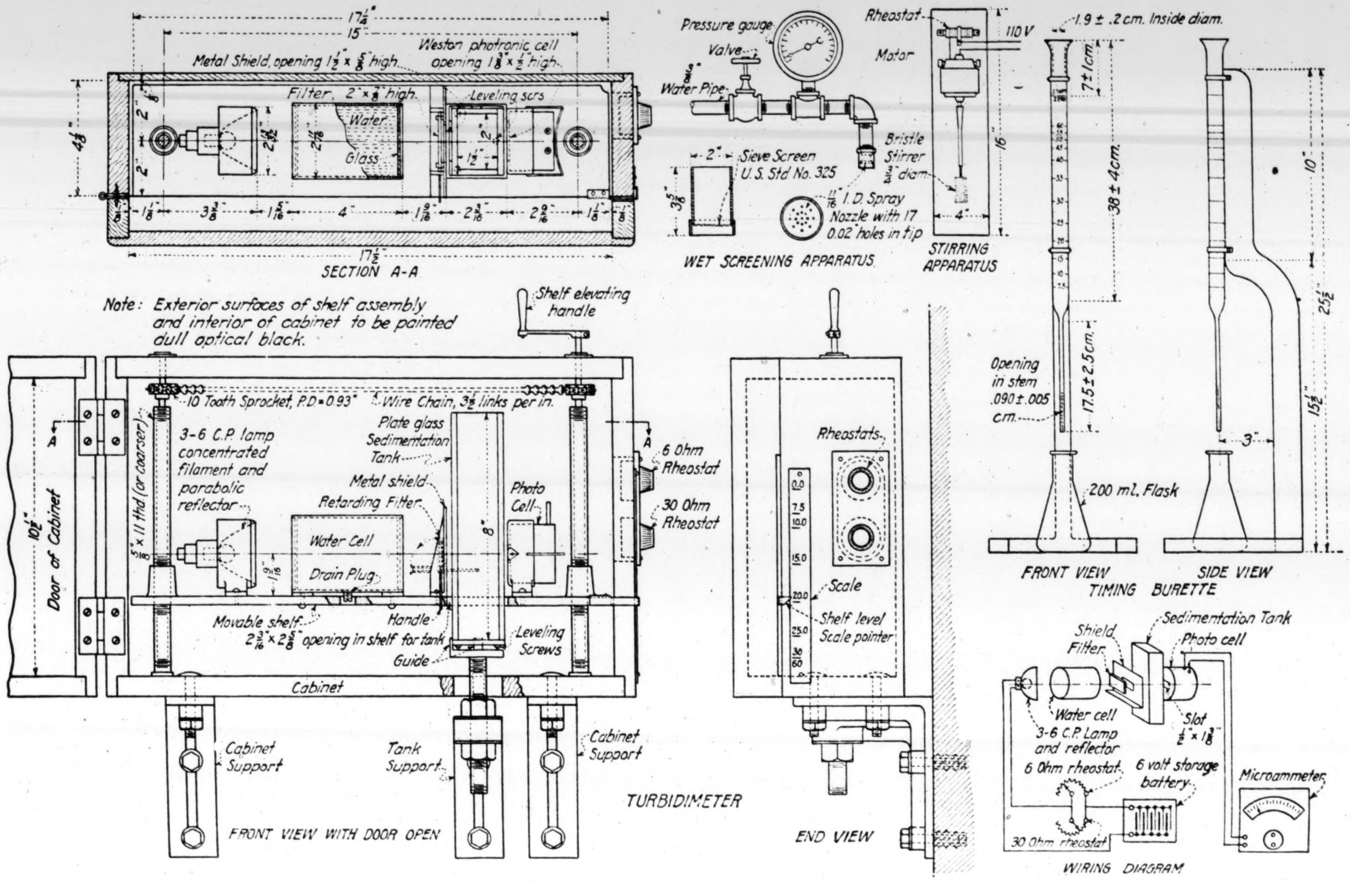
17¼"
15"
Metal Shield, opening 1½" x ⅝" high.
Weston photronic cell opening 1⅜" x ½" high.
Filter, 2" x ⅞" high.
Leveling scrs
Water
Glass
4⅝"
17½"
SECTION A-A
Pressure gauge
Valve
⅜" Water Pipe
Sieve Screen U.S. Std No. 325
11/16" I.D. Spray Nozzle with 17 0.02" holes in tip
Bristle Stirrer ¾" diam.
WET SCREENING APPARATUS
Rheostat
Motor
110 V
16"
4"
STIRRING APPARATUS
1.9 ± .2 cm. Inside diam.
7 ± 1 cm.
38 ± 4 cm.
17.5 ± 2.5 cm.
Opening in stem .090 ± .005 cm.
200 ml. Flask
10"
25½"
15½"
3"
FRONT VIEW
SIDE VIEW
TIMING BURETTE
Note: Exterior surfaces of shelf assembly and interior of cabinet to be painted dull optical black.
Shelf elevating handle
10 Tooth Sprocket, P.D. = 0.93"
Wire Chain, 3½ links per in.
3-6 C.P. lamp concentrated filament and parabolic reflector
Plate glass Sedimentation Tank
Metal shield
Retarding Filter
Photo Cell
Water Cell
Drain Plug
8"
A
6 Ohm Rheostat
30 Ohm Rheostat
10½"
Door of Cabinet
⅝" x 11 thd (or coarser)
Movable shelf
2 3/16" x 2⅝" opening in shelf for tank
Handle
Guide
Leveling Screws
Cabinet
Cabinet Support
Tank Support
Cabinet Support
FRONT VIEW WITH DOOR OPEN
TURBIDIMETER
Rheostats
Scale
Shelf level Scale pointer
END VIEW
Shield
Filter
Sedimentation Tank
Photo cell
Water cell
3-6 C.P. Lamp and reflector
6 Ohm rheostat
Slot ½" x 1⅜"
6 volt storage battery
Microammeter
30 Ohm rheostat
WIRING DIAGRAM

FIG. 2.—Dimensional Details of Turbidimeter Fineness Test Apparatus.

inside dimensions 2 by 1½ in. by 8 in. in height. The 2-in. faces of the tank shall be placed normal to the beam of light, and shall be equidistant within 0.003 in. at all points. A mark shall be placed on the side of the tank to indicate a volumetric content of 335 ml., which is the level to which the tank will be filled in a test.

(*e*) *Photoelectric Cell.*—The means of measuring the light intensity shall be a sensitive photoelectric cell (Weston Photronic type) connected directly to a microammeter. A hood with a horizontal slot ½ in. in height by 1⅜ in. in width shall be mounted over the face of the photoelectric cell.

(*f*) *Shield.*—A metallic shield having a slot ⅝-in. in height by 1½ in. in width, as indicated in Fig. 2, shall be placed between the water cell and the sedimentation tank.

(*g*) *Elevating Device.*—The source of light, water cell, photoelectric cell, retarding filter and shield shall be mounted on a movable shelf which is raised or lowered by two connected lead screws so that the turbidity of the suspension may be determined at any desired depth. The sedimentation tank shall be mounted on a base which is independent of the rest of the apparatus so that the tank shall be free from vibration caused by moving the shelf. The level of the light beam with reference to the surface of the suspension shall be indicated by a pointer which will travel along a scale mounted on the cabinet. The zero of the scale shall indicate that position at which the center lines of the slots for the light beam are at the same elevation as the surface of the liquid in the tank when filled to the 335-ml. level. The lines on the scale to be marked 7.5, 10, 15, 20, 25, and 30–60, shall be located at distances from the zero mark equal to values "h" in Table I, and shall indicate the positions at which the pointer should be located when turbidity readings for these particle sizes are taken. The interior of the turbidimeter cabinet and the exterior surfaces of the shelf, parabolic reflector, water cell, shield and photoelectric cell hood shall be painted with a dull optical black paint.

Microammeter

4. The microammeter shall have a range of 0 to 50 microamperes, shall be readable to 0.1 microampere, and accurate to 0.25 microampere. The internal resistance of the microammeter shall be between 95 and 105 ohms.

Battery

5. A 6-v. automobile starting and lighting storage battery shall be used for supplying current to the lamp.

Sieving Apparatus

6. The sieve shall be 2 in. in diameter and have side walls 3 in. in height, and shall be fitted with a No. 325 wire screen cloth, which cloth shall conform to the requirements of the Tentative Specifications for Sieves

for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials,[1] and be such that the sieving correction obtained shall not be greater than 15 per cent (see Section 10 (*b*)).

Stirring Apparatus

7. The stirring apparatus shall consist of either (*a*) a cylindrical brush, $\frac{3}{4}$ in. in diameter and about $1\frac{3}{4}$ in. in length, with an end approximately fitting the contour of the bottom of a $\frac{7}{8}$-in. diameter test tube, or (*b*) any other stirring device which will be equally efficient in dispersion as measured by specific surface determinations on a standard sample. The stirring apparatus shall rotate at a speed of approximately 3500 r.p.m.

Timing Burette

8. The time of settling for the different sized particles shall be obtained from a burette from which kerosine is allowed to flow. The burette shall consist of a glass tube having a capillary tube fused into the lower end. The upper end of the large tube shall be flared to serve as a funnel for introducing kerosine into the tube. The burette shall conform to the following limiting dimensions:[a]

	DIMENSION, CM.	PERMISSIBLE VARIATION, CM.
Length of large tube	38	± 4
Inside diameter of large tube	1.9	± 0.2
Length of capillary	17.5	± 2.5
Diameter of capillary	0.09	± 0.005
Top of burette to zero line	7	± 1

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[a] Since glass tubing of desired dimensions is not always obtainable, the above wide permissible variations allow selection of dimensions to produce a burette having a duration of flow which will permit of calibration as described in Section 10.

Suspending Liquid

9. At least 20 gal. of any clear white kerosine shall be set aside for use with the turbidimeter apparatus.

CALIBRATION OF APPARATUS

Calibration of Turbidimeter

10. The turbidimeter apparatus shall be calibrated in accordance with the following procedure:

(*a*) *Calibration of Burette Scale.*—For calibration of the burette scale a kerosine having a known viscosity and density for the temperature at which the calibration is to be made shall be used. The times of flow from the burette which correspond to the times of settling for the different sized particles shall be calculated from the following equation:

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[1] See p. 1289.

$$t = \frac{1{,}837{,}000\, u}{(P_1 - P_2)} \times \frac{h}{d^2} \ldots\ldots\ldots\ldots (1)$$

where t = time of settling, or time of flow in seconds;
u = viscosity of kerosine in poises;
P_1 = density of cement particles in grams per cubic centimeter = 3.15 for portland cement;[a]
P_2 = density of kerosine in grams per cubic centimeter;
h = depth of suspension to level of light in centimeters, and
d = diameter of particle in microns.

Values of $\frac{h}{d^2}$ are given in Table I.

TABLE I.—VALUES OF h, d, AND $\frac{h}{d^2}$ TO BE USED IN CALIBRATION OF THE TURBIDIMETER APPARATUS.

Particle Diameter, d, microns	Depth of Suspension, h, cm.	$\frac{h}{d^2}$	Settling Period, equals time of flow for burette, t, seconds
60	15	0.00417	This column to be calculated from Equation (1).
55	15	0.00496	
50	15	0.00600	
45	15	0.00741	
40	15	0.00938	
35	15	0.01225	
30	15	0.01667	
25	13.1	0.0210	
20	10.0	0.0250	
15	6.6	0.0293	
10	3.3	0.0333	
7.5	2.1	0.0375	

The burette shall next be filled with kerosine at the calibrating temperature, a timing clock shall be started at the instant the kerosine in the burette drains past the zero line, and levels reached by the draining kerosine shall be marked on the burette for each of the time intervals, t, calculated as described above. At these marks permanent lines and numbers indicating the corresponding diameters shall be etched on the burette (Note).

NOTE.—By using the calibrated burette the apparatus may be used within the normal range of room temperatures without further correction, the change in rate of flow of the kerosine from the burette automatically compensating for change in viscosity of the suspension due to temperature. The kerosine in the burette and that of the suspension should be kept the same within 1 F. (0.5 C.). This condition will ordinarily exist if the supply of kerosine is kept in the same room as the apparatus.

Extreme care must be taken to ascertain that only clean kerosine is used in the burette, and in addition the capillary should be examined frequently to make sure that no small pieces of lint or other foreign material have become lodged in it.

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[a] The specific gravity of portland cement does not vary greatly and in this work it is considered constant at 3.15. A variation of 0.15 from this value when substituted in Stokes' law gives a variation of 2.5 per cent in the diameter of the particle measured.

(*b*) *Calibration of the No. 325 Sieve.*—The spray nozzle and pressure gage shall be connected to a water supply line and the pressure on the spray nozzle adjusted to 10 lb. per sq. in. One gram of National Bureau of Standards' Standard Sample No. 114[a] shall be placed in the No. 325 sieve and washed for 1 min. The sieve and residue shall be dried in an oven or over a hot plate (Note 1) and the residue brushed from the sieve and weighed on an analytical balance (Note 2). The difference between the amount of residue obtained in this manner and the amount of residue indicated by the fineness specified for the standard sample, expressed as a percentage of the latter residue, shall be the sieve correction (Note 3).

NOTE 1.—Care should be taken not to heat the sieve hot enough to soften the solder.

NOTE 2.—After three determinations the sieve should be dipped in a 10 per cent solution of HCl and immediately rinsed with water to remove particles lodged in the meshes. After 25 determinations the sieve should be recalibrated.

NOTE 3.—It should be observed that the sieve correction as specified is a *factor* to be *multiplied* by the residue obtained and that the amount to be added or subtracted from the residue in any given test is therefore proportional to the amount of residue.

(*c*) *Determination of the Proper Light Intensity, I_0.*—The calibration of the turbidimeter proper shall be made by adjustment of the light intensity, I_0. Increasing the light intensity reduces the calculated surface area of any sample and *vice versa*. Using the regular test procedure described in Sections 12 to 14, and with the light adjusted to a trial value of 25 microamperes through the filter, a determination of the specific surface shall be made using National Bureau of Standards' Standard Sample No. 114.[a] If a specific surface greater than that assigned for the standard sample is obtained, the light intensity through the filter shall be increased, the suspension shall be re-agitated and the analysis repeated. If a specific surface less than the assigned value is obtained, the light intensity shall be decreased, the suspension re-agitated and the analysis repeated. When the intensity is found which results in the specific surface within ± 15 sq. cm. of the value assigned to the standard sample the tank shall be removed and the intensity through the filter recorded. Using new suspensions, the above procedure shall be repeated twice, and the average of the three intensities noted. The light shall next be adjusted to this average value and a tank of clear kerosine placed in its path. The intensity through the filter plus tank of clear kerosine shall be recorded. This becomes the permanent reference value for the intensity of the light, and the rheostats shall be adjusted at the beginning of each test to give this value through the filter plus tank of clear kerosine from the regular supply.

TEST SAMPLE

Size of Test Sample

11. The size of the sample of cement shall be so selected that the microammeter readings will fall in the middle portion of the microammeter scale (Note).

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[a] Obtainable at the National Bureau of Standards, Washington, D. C.

NOTE.—The following approximations will be helpful in many instances in selecting the size of sample; 0.3-g. sample for a cement of which more than 85 per cent passes a No. 325 sieve; 0.4-g. sample for a cement of which 70 to 85 per cent passes a No. 325 sieve; 0.5-g. sample for a cement of which less than 70 per cent passes a No. 325 sieve.

TEST PROCEDURE

Sieve Determination

12. A No. 325 sieve determination shall be made on a 1-g. sample of the cement in accordance with the procedure specified for calibration in Section 10 (*b*). The percentage of cement passing the sieve shall be noted and recorded as ***r***.

Preparation of the Suspension

13. (*a*) The cement sample shall be placed in a test tube with 10 to 15 ml. of kerosine and 5 drops of oleic acid (U.S.P.). (Oleic acid is added as a dispersing agent and has slight or no effect on the viscosity of the kerosine. The oleic acid should be kept in a well-stoppered dark-glass bottle.) The mixture shall then be stirred for 1 min. with the apparatus described in Section 7, and shall then be transferred to the settling tank, the brush and tube washed with clear kerosine which shall also be added to the suspension, and clear kerosine added until the total volume of the suspension in the tank is 335 ml. (Note).

NOTE.—Since it is important that the level of the liquid in the tank coincide with the zero mark on the scale of the instrument (see Section 3 (*g*)), it is correspondingly important that the volume of the suspension be close to 335 ml., as specified. This may be accurately determined by the use of a calibrated flask of 335-ml. capacity, from which all the kerosine used in making up a suspension is taken; or a point gage may be used, consisting essentially of a flat plate approximately 2 by 2½ in. to the center of which is attached vertically a metal pin of such length that, when the plate is placed in position on top of the tank, the point of the pin is at the 335-ml. level. Either of these methods should insure the position of the liquid level within a few tenths of a millimeter.

(*b*) *Agitation of the Suspension.*—The tank shall be agitated just before being placed in the path of the light beam to effect a uniformity of the suspension. The tank shall be covered with a ground-glass cover and oscillated 180 deg. about a horizontal axis turning the tank upside down and back again to its original upright position once each second for 1 min. (Note 1). Care should be taken to prevent loss of kerosine (Note 2). The suspension will then be ready to place in its proper position in the path of the light beam.

NOTE 1.—The procedure described for oscillating the suspension must be carefully followed. The procedure used in shaking a cocktail must not be used.

NOTE 2.—The faces of the glass tank may be wiped only when the tank does not contain a suspension of the cement particles. Wiping the tank may generate static electricity and interfere with the free fall of the particles.

Test Procedure

14. The turbidimeter apparatus shall be operated in accordance with the test procedure described in tbe following Paragraphs (*a*) to (*h*):

(*a*) With retarding filter and sedimentation tank containing approximately 100 ml. of clear kerosine in the light path, the light shall be adjusted to the proper intensity, I_0, by taking repeated readings at 1-min. intervals until an unchanging value shall indicate that the lamp and photoelectric cell are in equilibrium (Note).

NOTE.—The lamp must never be turned on without a suspension or the retarding filter in position to reduce the light intensity to a value within the range of the microammeter.

(*b*) The proper size of sample of cement (Section 11) shall be weighed and a suspension prepared in accordance with Section 13.

(*c*) The shelf level pointer shall be placed at the 30–60-micron position.

(*d*) The burette shall be filled with kerosine and oscillation started in accordance with Section 13 (*b*). The oscillation shall be continued until the kerosine drains to the zero line on the burette, when the agitation shall be stopped (Note). The tank shall be immediately placed in position in the path of the light beam.

NOTE.—The lid to the tank must fit so that no kerosine drains down the outside faces of the tank.

(*e*) The retarding filter shall be immediately removed from the light path and the cabinet door closed.

(*f*) The microammeter shall be read at the instants the kerosine in the burette drains past marks 60, 55, 50, 45, 40, 35 and 30.

(*g*) The shelf shall then be raised successively to the marks 25, 20, 15, 10 and 7.5 on the pointer scale, the microammeter being read at each position as the kerosine drains past the corresponding mark on the burette.

(*h*) The filter shall be replaced in the path of the light beam, the tank removed and the intensity of the lamp checked (Note).

NOTE.—If the intensity of the lamp has shifted more than 0.3 microampere from the initial setting (I_0), the test must be repeated. A freshly charged storage battery should be momentarily short-circuited to reduce the voltage to constant value. If the intensity of the lamp continues to fluctuate, look for loose connections in the lamp and photo-cell circuits, see that the rheostat contacts are clean and make certain that the lamp, socket and reflector are rigidly fixed in their mounting.

CALCULATIONS

Calculation of Results

15. Calculation of the turbidimeter data shall be made in accordance with the following Paragraphs (*a*) to (*c*):

(*a*) *Specific Surface.*—Specific surface shall be calculated from the following equation:

$$S = \frac{38\, r\, (2 - \log I_{60})}{1.5 + 0.75 \log I_{7.5} + \log I_{10} + \log I_{15} + \log I_{20} \ldots\ldots\ldots\ldots\ldots + \log I_{55} - 11.5 \log I_{60}}$$

where S = the specific surface of the sample in square centimeters per gram;
r = the percentage by weight passing the No. 325 sieve, and
$I_{7.5}, I_{10}, I_{15} \ldots\ldots I_{60}$ = the microammeter readings, in microamperes, which correspond to the particle diameters 7.5, 10, 15......60 microns.

NOTE.—The constant factor 38 applies only to a material having the specific gravity of portland cement (approximately 3.15). For any other material there must be calculated the corresponding proper value for this factor which, in the derivation of the formula, varies inversely as the density of the particles (in grams per cubic centimeter).

(*b*) *Recording of Data.*—The following form is suggested for the recording of turbidimeter data and calculation of specific surface:

TABLE II.—FORM FOR RECORDING TURBIDIMETER TEST DATA AND CALCULATION OF SPECIFIC SURFACE.

(Values shown are for purpose of illustration.)

Sample Identification		Sample X
Passing No. 325 Sieve (wet method), r		89.7 per cent
Filter Reference	Before Test	20.5 microamperes
	After Test	20.5 microamperes
Weight of Sample Tested		0.3 g.

PARTICLE SIZE, MICRONS	I, MICROAMPERES	LOG I	
60	11.0	....	1.041[a]
55	11.1	1.045	
50	11.3	1.053	
45	11.5	1.061	
40	11.7	1.068	
35	12.1	1.083	
30	12.6	1.100	
25	13.4	1.127	
20	14.4	1.158	
15	15.7	1.196	
10	19.1	1.281	
7.5	23.0	....	1.362[a]

$0.75 \times 1.362 = 1.022$

1.500

Sum $= 13.694$

$11.5 \times 1.041 = 11.972$

Difference $= 1.722$

$$S = \frac{38 \times 89.7 \times 0.959}{1.722} = 1900 \text{ sq. cm. per gram}$$

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[a] For convenience in calculation, log I_{60} and log $I_{7.5}$ are recorded in a separate column.

(*c*) *Calculation of the Specific Surface from First Turbidity Reading,* I_{60}.—This method may be used for successive determinations from the same plant, provided, that the same size test samples are used, and that there is no great change in fineness, color, or other properties of the cement. Under these conditions the specific surface of a sample may be calculated from the first turbidity reading, I_{60}, by using the following equation:

$$S = c(2 - \log I_{60})$$

where S = the specific surface in square centimeters per gram;
I_{60} = the microammeter reading corresponding to particle diameter of 60 microns, and
c = the transmittancy constant for the particular plant.

NOTE.—The transmittancy constant "c" may be evaluated by substituting in the above equation known values of S and $2 - \log I_{60}$ as determined from a complete turbidimeter test. The average of not less than five values of "c," as determined from complete tests, should be used in the above equation.

Tentative Specifications for

HYDRAULIC HYDRATED LIME FOR STRUCTURAL PURPOSES[1]

A.S.T.M. Designation: C 141 - 38 T

ISSUED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Definition

1. *Hydraulic Hydrated Lime.*—An hydraulic hydrated lime is the hydrated dry cementitious product obtained by calcining a limestone containing silica and alumina to a temperature short of incipient fusion so as to form sufficient free lime (CaO) to permit hydration and at the same time leaving unhydrated sufficient calcium silicates to give the dry powder, meeting the requirements herein prescribed, its hydraulic properties.

(*a*) High Calcium Hydraulic Hydrated Lime is a lime that contains not more than 5 per cent magnesium oxide (of the nonvolatile portion).

(*b*) Magnesium Hydraulic Hydrated Lime is a lime containing more than 5 per cent magnesium oxide (of the nonvolatile portion).

Uses

2. Hydraulic hydrated lime may be used for scratch or brown coat of plaster, for stucco, for mortar, and as sole cementitious material in concrete, or in portland-cement concrete either as blend, amendment, or admixture.

SPECIFICATIONS

Chemical Limits

3. The hydraulic hydrated lime shall conform to the following requirements as to chemical composition, calculated to the nonvolatile basis:

	MINIMUM	MAXIMUM
Calcium and magnesium oxides (CaO and MgO), per cent...	60	70
Silica (SiO_2), per cent..........	16	26
Iron and aluminum oxides (Fe_2O_3 and Al_2O_3), per cent...	..	12
Carbon dioxide (CO_2), per cent...		5

Fineness

4. The sample shall leave a residue of not more than 0.5 per cent on a No. 30 sieve and not more than 10 per cent on a No. 200 sieve when tested as described in Section 18.

Time of Setting

5. The neat hydraulic hydrated lime paste mixed to normal consistency shall not develop an initial set in less than 2 hr. as determined by the Gillmore needle

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-7 on Lime.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

method. Final set shall be attained within 48 hr.

Soundness

6. Pats of neat hydraulic hydrated lime made and stored as described in Section 22 shall be firm and hard and show no signs of distortion, cracking, or disintegration under both conditions of storage. Mortar strength specimens at the time of test shall show no signs of distortion, cracking, or disintegration.

Compressive Strength

7. The average compressive strength of not less than three 2-in cubes, made, stored, and tested in accordance with Sections 23 to 28, shall be not less than 175 psi. at the age of 7 days. The average strength attained at 28 days shall be not less than that attained at 7 days.

Packaging and Marking

8. The hydraulic hydrated lime shall be delivered in suitable containers with the brand and name of the manufacturer and the net weight plainly marked thereon. A bag shall contain 62.5 lb. net. A barrel shall contain 250 lb. net. All packages shall be in good condition at the time of inspection. Packages varying more than 10 per cent from the weight marked thereon may be rejected, and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than the weight marked thereon, the entire shipment may be rejected.

Storage

9. The hydraulic hydrated lime shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the hydraulic hydrated lime from damage.

Inspection

10. Every facility shall be provided the purchaser for sampling and inspection either at the place of manufacture or at the destination, as may be specified by the purchaser.

Rejection

11. The hydraulic hydrated lime may be rejected if it fails to meet any of the requirements of these specifications. However, hydraulic hydrated lime failing to meet the 7-day requirements may be held awaiting the result of the 28-day tests before rejection. At least ten days from the time of sampling shall be allowed for completion of the 7-day test, and at least thirty-one days shall be allowed for completion of the 28-day test.

SAMPLING AND METHODS OF TESTING

Size and Number of Samples

12. Each sample selected for purpose of tests shall weigh at least 5 lb. and shall represent not more than 200 bbl. If only one sample is taken it shall weigh at least 10 lb.

Shipment of Samples

13. Samples shall be shipped and stored in airtight, moistureproof containers.

Chemical Analysis

14. Analyses for chemical composition shall be carried out in accordance with the Standard Methods of Chemical Analysis of Limestone, Quicklime, and Hydrated Lime (A.S.T.M. Designation: C 25) of the American Society for Testing Materials.[3]

Physical Tests

15. All physical test procedures not otherwise specified shall be carried out in accordance with the Standard Meth-

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[3] 1936 Book of A.S.T.M. Standards, Part II, p. 51.

ods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials.[4]

Standard Temperature

16. The standard temperature shall be 70 F. (21 C.). The air of the laboratory, the materials, the mixing water, the moist closet, and storage tanks shall be maintained as nearly as practicable at the standard temperature and shall not vary therefrom more than 5 F. (3 C.).

Preliminary Treatment of Samples

17. The sample shall be given a preliminary sieving by being passed through a No. 20 sieve in order thoroughly to mix the sample, break up lumps, and remove foreign materials.

Fineness Test

18. (*a*) *Apparatus.*—The No. 30 and No. 100 sieves shall conform to the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[5]

(*b*) *Procedure.*—A 100-g. sample of the material as received shall be placed on a No. 30 sieve, which shall be nested above a No. 200 sieve. The material shall be washed by means of a stream of water from a faucet (Note 1). The washing shall be continued until the water coming through the sieve is clear, but in no case shall the washing be continued for more than 15 min. (Note 2). The residue on both sieves shall be dried to constant weight at a temperature between 212 and 248 F. (100 and 120 C.). The weights of material retained shall be calculated as a percentage of the original sample, the weight of the material retained on the No. 30 sieve being added to the weight of the material retained on the No. 200 sieve to obtain the correct weight of the material retained on the No. 200 sieve.

NOTE 1.—A piece of rubber tubing attached to a water faucet may be used for the washing. The velocity of the water which may be increased by pinching the tubing, shall not be sufficient to cause any splashing of the sample over the sides of the sieve.

NOTE 2.—Care shall be taken not to let water accumulate on the No. 200 sieve, because the openings will become clogged and the operation cannot be completed in 15 min.

Mixing Paste

19. Hydraulic hydrated lime pastes shall be mixed in accordance with Sections 25 to 27 of Standard Methods C 77,[4] except that the operation of mixing, squeezing, and kneading with the hands shall be continued for 5 min.

Normal Consistency

20. Normal consistency shall be determined by the Vicat apparatus in accordance with Sections 29 and 30 of Standard Methods C 77.[4]

Time of Setting Test

21. Time of setting shall be determined by the Gillmore needle method in accordance with Sections 39 and 40 of Standard Methods C 77.[4] The hydraulic hydrated lime pats shall be stored during the test in a damp closet maintained at a relative humidity of 90 per cent or more.

Soundness Test

22. Two pats of hydraulic hydrated lime paste of normal consistency (Section 20) shall be used for making soundness tests. After the first 48 hr. in the damp closet one of the pats shall be stored in the air of the laboratory for 5 days and the other shall be immersed for 5 days in clean running water in storage tanks of suitable materials. Unsoundness is manifested by change in volume, which causes distortion, cracking, checking, or disintegration. Pats

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[4] 1937 Supplement to Book of A.S.T.M. Standards, p. 54.
[5] See p. 1289.

improperly made or exposed to drying may develop what is known as shrinkage cracks within the first 24 hr. The shrinkage cracks are not an indication of unsoundness. The mere failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached do not indicate unsoundness. Should the pat leave the plate, distortion may be detected with a straightedge applied to the surface which was in contact with the plate, provided the glass plate was flat before test.

Compressive Strength Test

23. *Test Specimen.*—The compression test specimen shall be a 2-in. cube. The molds shall be of noncorrodible metal and shall be so designed as to prevent spreading during molding. Molds shall be oiled with a mineral oil before using.

24. (*a*) *Proportions for Standard Mortar.*—The mortar shall consist of 1 part of hydraulic hydrated lime to 3 parts of standard Ottawa sand, by weight. Ottawa sand shall conform to the requirements of Sections 42 to 44 of Standard Methods C 77.[4]

(*b*) *Preparation of Standard Mortar.*—The mortar shall be mixed in a nonabsorbent bowl of about 1-gal. capacity. A measured quantity of water shall be poured into the bowl which previously has been wiped with a damp cloth. A 500-g. sample of the hydraulic hydrated lime shall then be added and stirred into the water with the fingers of one hand until all of the hydraulic hydrated lime is wetted. Approximately 800 g. of sand shall then be added and the stirring continued for 30 sec. The remainder of 1500 g. of sand shall then be added and the mortar mixed for 75 sec. by vigorous and continued stirring, squeezing, and kneading with one hand. The mortar shall be allowed to stand for 60 sec. and then mixed for another 60 sec. During the operation of mixing, the hands shall be protected by rubber gloves. The top of the flow table (see Paragraph (*c*)) shall be carefully wiped dry and the flow mold placed at the center and filled with the mortar. In filling the mold the mortar shall not be rammed, but gently puddled to insure uniform filling. The mortar shall be smoothed off level with the top of the mold by aid of a trowel and the mold then removed. Immediately, the table shall be dropped through a height of $\frac{1}{2}$ in., 25 times in 15 sec. The flow is the resulting increase in diameter of the mortar mass, expressed as a percentage of the original diameter. The mortar shall be of standard consistency when the flow is 100 to 115. Trial mortars shall be made with varying percentages of water until the standard consistency is obtained. Each trial shall be made with fresh mortar. The quantity of water shall be expressed as a percentage of the weight of the combined dry materials.

(*c*) *Flow Table.*—The flow table apparatus shall consist of a rigid frame with a flat circular top, so mounted on a vertical shaft that it can be raised and dropped $\frac{1}{2}$ in. by means of a cam. The top shall be of noncorrodible metal, 10 in. in diameter, and with the attached shaft shall weigh 9 lb. The mold shall be of noncorrodible material, 4 in. in inside diameter at the base, $2\frac{3}{4}$ in. in inside diameter at the top, and 2 in. in height.

25. *Molding of Test Cubes.*—The surfaces of the molds and plates to be in contact with the cubes shall be oiled with a medium viscosity oil. The molds shall be half filled with mortar, the mortar puddled into place with the finger tips of the gloved hand, the mold then filled to overflowing and the mortar again puddled with the finger tips. The

mortar shall then be troweled off flush with the top of molds.

26. *Storage of Test Cubes.*—All test pieces, immediately after molding, shall be kept in the molds on plane plates in a damp closet, maintained at a relative humidity of 90 per cent or more for from 48 to 52 hr. in such a manner that the upper surfaces shall be exposed to the moist air. The cubes shall then be removed from the molds and placed in the air of the laboratory for 5 days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of 7 days the cubes for the 28-day tests shall be immersed in clean running water in storage tanks of noncorrodible materials.

27. *Testing of Cubes.*—The compressive strength test may be made with any type of verified compression testing machine of suitable capacity. Those faces of the cube which when molded were in contact with the sides of the molds shall be placed in contact with the surfaces through which the load is applied. A spherical-seated bearing block shall be used between the upper face of the cube and the head of the testing machine. The center of the sphere shall lie in that surface of the bearing block which is in contact with the cube, and the radius of the sphere shall be 1½ in. The cube shall be carefully centered in the testing machine and below the center of the bearing block. Cushioning materials shall not be used. The load shall be applied uniformly and without shock. The moving head of the testing machine shall travel at the rate of approximately 0.05 in. per min. when the machine is running idle.

28. *Calculation of Compressive Strength.*—The total load indicated by the testing machine at failure of the test cube shall be recorded, and the unit compressive strength calculated in pounds per square inch of the cross-sectional area of the cube. Cubes that are manifestly faulty, or which give strengths differing by more than 15 per cent from the average value of all test cubes made from the same sample and tested at the same period, shall not be considered in determining the compressive strength.

TENTATIVE METHODS OF PHYSICAL TEST
FOR
LIMESTONE, QUICKLIME AND HYDRATED LIME[1]

A.S.T.M. Designation: C 110 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1938.

RESIDUE

Apparatus

1. The sieves used shall conform to the requirements of the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2]

Residue of Quicklime

2. A representative 2½-kg. (5-lb.) sample of the quicklime shall be selected. Lime selected for this test shall be broken so as to entirely pass a 1-in. ring and be retained on a ¼-in. sieve. Pulverized lime shall be tested as received. The sample shall be placed in a box of wood or of some material of similarly low thermal conductivity and slaked by an experienced operator with sufficient water at 70 to 80 F. (21 to 27 C.) to produce the maximum quantity of lime putty, care being taken to avoid "burning" or "drowning" the lime. It shall be allowed to stand for 1 hr. and then washed through a No. 20 sieve by a stream of water having a moderate pressure. No material shall be rubbed through the sieve. The washing shall be continued until the residue on the screen appears to consist entirely of coarse particles, but in no case shall the washing be continued for more than 30 min. The residue shall be dried to constant weight at a temperature of 212 to 225 F. (100 to 107 C.) and the percentage residue calculated, based on the original weight of the sample.

Residue of Hydrated Lime

3. A 100-g. sample of the hydrated lime as received shall be selected and placed on a No. 30 sieve, which shall be nested above a

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee C-7 on Lime.

These Tentative Methods, when adopted as standard, will be added to the present Standard Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (A.S.T.M. Designation: C 25 - 29), see 1936 Book of A.S.T.M. Standards, Part II, p. 51.

[2] See p. 1289.

No. 200 sieve. The material shall be washed through the sieves by means of a stream of water from a faucet. A piece of rubber tubing attached to the water faucet shall be used for the washing. The velocity of the water may be increased by pinching the tubing, but shall not be sufficient to cause any splashing of the sample over the sides of the sieve. The washing shall be continued until the water coming through the sieve is clear, but in no case shall the washing be continued for more than 30 min. Care shall be taken not to let water accumulate on the No. 200 sieve, because the openings will become clogged and the operation cannot be completed in 30 min. The residues on both sieves shall be dried to constant weight in an atmosphere free from carbon dioxide at a temperature between 212 and 248 F. (100 and 120 C.). The percentage residue retained on each sieve shall be calculated, based on the original weight of the sample. The weight of the material retained on the No. 30 sieve shall be added to the weight of the material retained on the No. 200 sieve to obtain the correct weight of the material retained on the No. 200 sieve.

STANDARD CONSISTENCY OF LIME PUTTY

Apparatus

4. (*a*) *Modified Vicat Apparatus.*—The modified Vicat apparatus shown in Fig. 1 shall be used. This consists of a bracket, *A*, bearing a movable brass rod, *B*, 6.3 mm. in diameter and of suitable length to fit the Vicat bracket. On the lower end of the rod is attached a plunger, *C*, 12.5 mm. in diameter, made of aluminum tubing. The total weight of the rod with plunger shall be 30 g. The lower end of the plunger shall be closed without shoulders or curvature and the tube may be loaded with shot to the specified weight. The total weight required may also be obtained by means of a weight, *D*, screwed into the rod. The rod can be held in any position by means of a screw, *E*, and has a mark midway between the ends which moves under a scale, *F*, graduated in millimeters, attached to the bracket, *A*.

(*b*) *Mold.*—The conical ring mold shall be made of a non-corroding, non-absorbent material, and shall have an inside diameter of 7 cm. at the base, 6 cm. at the top and a height of 4 cm.

(*c*) *Base Plate.*—The base plate for supporting the ring mold shall be of plate glass and about 10 cm. square.

Standard Consistency Determination

5. (*a*) *Procedure.*—Standard consistency of lime putty shall be measured as follows: About 300 g. of hydrated lime shall be mixed with sufficient water to form a thick putty and stirred with a trowel or spatula for 2 or 3 min. to insure intimate mixing. After aging in

a vessel covered with a damp cloth for not less than 16 nor more than 24 hr., this putty shall again be stirred for 2 or 3 min. and a sufficient quantity placed in the ring mold resting on the glass base plate. The mold shall be placed with its larger end resting on the base plate and after filling, the lime putty shall be struck off flush with the top of the mold. The lime putty, confined in the ring mold, resting on the plate, shall then be centered under the rod of the modified Vicat apparatus, Fig. 1. The plunger end, *C*, shall then be brought in contact with the surface of the lime putty and an initial reading taken. The rod shall then be released and the final reading shall be taken 30 sec. after the plunger is released.

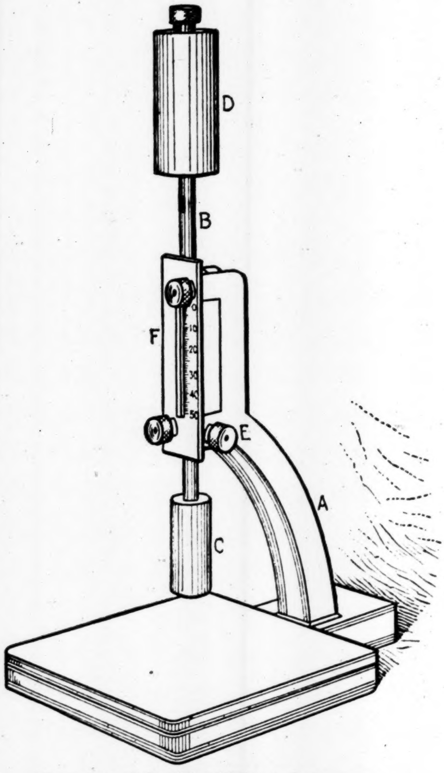

FIG. 1.—Modified Vicat Apparatus.

(*b*) *Standard Consistency.*—The lime putty shall be of standard consistency when a penetration of 20 mm. is obtained in 30 sec. A permissible variation of ±5 mm. is allowed in preparing the sample for the plasticity determination described in Section 6.

(*c*) If the penetration is less than standard, the sample may be removed from the mold, combined with the original aged putty, the whole mixed with more water, stirred for 2 or 3 min., and a suitable quantity retested. If the penetration is more than standard, the sample shall be discarded and a new one prepared.

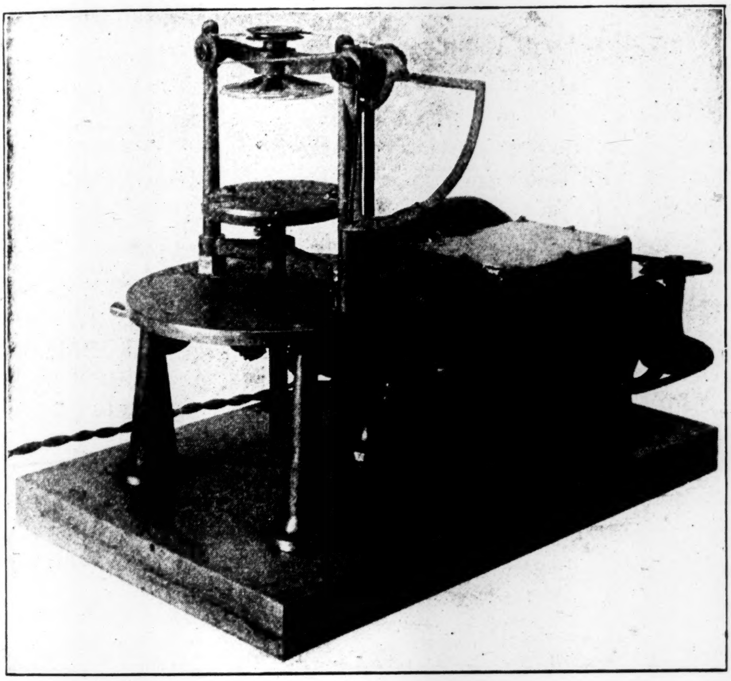

FIG. 2.—Emley Plasticimeter.

Constants of the Machine:

Absorption of porcelain base plate.—Minimum of 40 g. in 24 hr. For rate of absorption of base plates, see Section 9.

Dimension of base plate.—1 in. in thickness by 4 in. in diameter.

Dimensions of disk.— $\frac{1}{32}$ in. in thickness by 3 in. in diameter.

Speed of vertical shaft.—One revolution in 6 min., 40 sec.

Upward movement of base plate.— $\frac{1}{13}$ in. per revolution.

Torque on disk when bob reading is 100.—14,400 g.c.m.

PLASTICITY OF LIME PUTTY

Plasticity Determination

6. (*a*) Plasticity of lime putty shall be determined by means of the apparatus shown in Fig. 2 as follows: A ring mold such as is described in Section 4 (*c*) shall be lubricated with a thin film of water, placed on a porcelain base plate (see Sections 8 and 9), filled with the paste which has been adjusted to standard consistency as de-

scribed in Section 5, and struck off level. The mold shall be removed by raising it vertically without distorting the paste. The base plate and paste shall be centered in the instrument and the carriage turned up by hand until the surface of the paste is in contact with the disk and the distance between the disk and the top of the base plate is 32 mm. (1¼ in.). The carriage shall then be thrown into gear and the motor started. It is essential that the motor shall be started exactly 120 sec. after the first portion of the paste has been placed in the mold. The time when the first portion of paste is placed in the mold shall be recorded as zero time—the motor is therefore started at 2 min. Care shall be taken to protect the specimen from drafts during the test.

(*b*) The scale reading shall be recorded every minute until the test is completed. The test shall be considered complete when (*1*) the scale reading reaches 100; (*2*) any reading is less than the one before; or (*3*) the scale reading remains constant for three consecutive readings (2 min.) and the specimen has visibly ruptured or broken loose from the base plate. The time and the scale reading at the end of the test shall be noted.

Calculation

7. The plasticity figure shall be calculated from the following formula:

$$P = \sqrt{F^2 + (10T)^2}$$

where P = the plasticity figure;
F = the scale reading at the end of the test; and
T = the time in minutes from when the first portion of paste was put in the mold to the end of the test.

Cleaning and Care of Base Plates

8. In making plasticity determinations much of the success attainable depends upon the condition of the base plates. Continued use of the plates without proper cleaning results in clogging of the pores, with reduction in the rate of absorption. After a plate has been used the excess lime shall be wiped off and the plate immersed in clear water for not less than 2 hr., after which it shall be transferred without drying to a dilute solution of HCl (1:9) where it shall be kept immersed for another 2 hr. It shall then be transferred to a receptacle containing running water for at least 1 hr. The plate is then free of acid and, after the removal of excess water, shall be placed in an oven overnight at a temperature of between 212 and 230 F. (100 and 110 C.) for drying. Before using, the plate shall be cooled to room temperature.

Absorption of Plasticimeter Base Plates

9. (*a*) *Total Absorption.*—Plasticimeter base plates when immersed in water at room temperature for a period of 24 hr. shall absorb not less than 40 g. of water. Before making the determination the plates shall be dried overnight in an oven at a temperature of between 212 and 230 F. (100 and 110 C.) and permitted to cool to room temperature. After immersion and before weighing, the excess water shall be wiped off with a damp cloth.

(*b*) *Rate of Absorption.*[1]—When tested over an area $2\frac{3}{4}$ in. in diameter the water absorbed shall be in accordance with the following:

	WATER ABSORBED, ML.
First minute	8 to 14
Second minute	5 to $7\frac{1}{2}$
Third minute	4 to $6\frac{1}{2}$
Fourth minute	4 to 6
Fifth minute	$3\frac{1}{2}$ to $5\frac{1}{2}$

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[1] A convenient apparatus for determining the rate of absorption consists of a burette sealed onto an inverted glass funnel from which the stem has been removed. The diameter of the larger end of the funnel shall be ground so as to be $2\frac{3}{4}$ in. in internal diameter. The funnel may be attached to the plate on which the measurement is being made by melted paraffin. The paraffin should not be too hot. A little experience will indicate when it is of the proper consistency.

TENTATIVE SPECIFICATIONS

FOR

PAVING BRICK[1]

A.S.T.M. Designation: C 7 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1913; ADOPTED, 1915; REVISED, 1930; REISSUED AS TENTATIVE, 1937; REVISED, 1937, 1938.

Scope

1. These specifications cover vitrified brick used in the construction of pavements.

MANUFACTURE

General Requirements

2. Paving brick shall be manufactured from fire clay, semi-fire clay or shale, or combinations thereof. The manufacturing process shall be such that the brick are thoroughly annealed, tough, durable and evenly burned so that, when broken, they show a uniformly dense structure free from lime, air pockets and marked laminations. The name of the brick or the manufacturer shall be impressed on the side or end of each brick in recessed letters.

Side Lugs

3. The brick shall be provided on one side with not less than two lugs, which shall be not less than $\frac{1}{8}$ in. nor more than $\frac{1}{4}$ in. in height. The area of the projections or lugs measured at the base of the lug shall not exceed in total area 3 sq. in. No lug shall be continuous from top to bottom of the brick, but shall be of a type that allows free horizontal flow of the filler.

End Lugs

4. Vertical fiber brick shall be provided with not less than two non-continuous lugs or portions of lugs on each end of each brick. Lugs shall be non-meshing and shall have a total base area of not more than $2\frac{1}{2}$ sq. in. and shall be manufactured so there may be free horizontal flow of the filler.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-15 on Manufactured Masonry Units.

These specifications are in effect a revision of and replace the former Standard Specifications for Paving Brick (C 7 - 30), which standard was accordingly discontinued in 1937.

The lugs shall project from the ends of the brick so as to insure an end joint of not less than $\frac{1}{8}$ in. nor more than $\frac{1}{4}$ in. in width.

Types and Sizes

5. Paving brick shall conform to the following types and nominal sizes. The dimensions of the brick shall be construed as applying to the body of the brick only, exclusive of lugs.

	DEPTH, IN.	WIDTH, IN.	LENGTH, IN.
Repressed Lug Brick	4	$3\frac{1}{2}$	$8\frac{1}{2}$
Vertical Fiber Lug Brick	$2\frac{1}{2}$	4	$8\frac{1}{2}$
	3	4	$8\frac{1}{2}$
	$3\frac{1}{2}$	4	$8\frac{1}{2}$

NOTE.—The above sizes and varieties are those recognized by the Permanent Committee on Simplification of Varieties and Standards for Vitrified Paving Brick, Simplified Practice Recommendation R 1–36, of the U. S. Department of Commerce, for the years 1936, 1937, and 1938, and are subject to change from year to year.

Repressed Brick

6. The edges of repressed brick shall be rounded to a radius of not more than $\frac{3}{16}$ in.

Permissible Variations in Size

7. For any lot of paving brick furnished under these specifications, the individual bricks shall not vary from the nominal size requirements specified in Section 5 by more than $\pm\frac{1}{8}$ in. in either transverse dimension, exclusive of kiln marks, or by more than $\pm\frac{1}{4}$ in. in length.

PHYSICAL PROPERTIES AND TESTS

Loss in Rattler Test

8. (*a*) The percentage of loss in the rattler test of the respective sizes of paving brick specified shall not exceed the following maximum limits:

SIZE OF BRICK		MAXIMUM LOSS IN RATTLER TEST, PER CENT
TRANSVERSE DIMENSIONS, IN.	LENGTH, IN.	
$2\frac{1}{2}$ by 4	$8\frac{1}{2}$	26
3 by 4	$8\frac{1}{2}$	24
$3\frac{1}{2}$ by 4	$8\frac{1}{2}$	22

(*b*) The total number of pieces weighing 1 lb. or more remaining after the completion of the rattler test shall not exceed 12.

VISUAL INSPECTION

Rejection by Visual Inspection

9. Paving brick shall be subject to visual inspection prior to shipment, after delivery, and during laying for the purpose of culling out and rejecting individual imperfect brick. Subject to the exceptions specified in Paragraph (*b*), individual brick may be culled and rejected for the following causes:

(*a*) *Variation in Size.*—Brick which vary from the nominal size specified in Section 5 by more than $\pm\frac{1}{8}$ in. in either transverse dimension, exclusive of kiln marks, or by more than $\pm\frac{1}{4}$ in. in length.

(*b*) *Broken or Chipped Brick.*—Brick which are chipped or broken so that neither wearing surface remains substantially intact, or so that the lower, or bearing surface is reduced in area more than 15 per cent, or are weakened structurally. However, brick so rejected but otherwise acceptable may be used for part-brick for beginning courses and for batting provided the portion so used meets all of the requirements for visual inspection.

(*c*) *Cracked Brick.*—Brick which are cracked to such a degree, either from shocks received in shipping and handling or from defective manufacture, as to produce defects described in Paragraph (*b*), unless such cracks are plainly superficial and insufficient to weaken the brick under the conditions of use.

(*d*) *Warped or Kiln-Marked Brick.*—Brick which are kiln-marked more than $\frac{3}{16}$ in. or which are misshapen, bent or twisted so that they will not form a proper surface, or align with other brick in conformance with the specifications for laying brick in the pavement. Vertical fiber brick shall have no kiln-marks in the wire cut surface.

(*e*) *Under-Burned Brick.*—Brick which are obviously too soft and too poorly vitrified to endure traffic wear. If disagreement on this requirement arises between the purchaser and the seller it shall be the right of the purchaser to make one or more rattler tests of the brick he wishes to exclude, and if in any or all tests the brick fail to conform to the requirements of these specifications, then all brick having the same objectionable appearance may be excluded.

ACCEPTANCE AND REJECTION

Basis of Acceptance

10. Acceptance of any lot of paving brick shall be based on the results of tests on samples representing that lot, subject only to rejection at any time of individually imperfect or unsatisfactory brick, in accordance with the requirements under Section 11.

Retesting

11. (*a*) If the percentage of loss in the rattler test on any sample exceeds by 2 per cent or less the maximum permissible rattler loss specified in Section 8 (*a*) for the size specified, or if the number of pieces weighing 1 lb. or more remaining after the completion of the rattler test exceeds 12 as specified in Section 8 (*b*), two additional tests shall be made. Each of these additional tests shall comply with the requirements of both Section 8 (*a*) and (*b*) and, in addition, the average rattler loss for the three tests shall not exceed the maximum permissible loss specified in Section 8 (*a*).

(*b*) Where a lot of paving brick is rejected for failure to meet the test requirements prescribed in these specifications, the purchaser may, at his option, permit the seller to regrade the rejected brick and again offer the brick for test and acceptance. The regraded brick shall be resampled and tested and if they again fail, the purchaser may definitely and finally reject the lot for which the test is representative.

Payment for Cost of Testing

12. Unless otherwise agreed, the seller shall furnish at the place of manufacture, without charge to the purchaser, the use of an approved rattler in efficient operating condition, conforming to the requirements specified in Section 15. Payment of the cost of testing shall be made by the purchaser, except that the cost of testing additional samples in accordance with Section 11, made necessary by the failure of any lot or lots, or of testing supplemental samples to determine the admissibility of a portion of any lot or lots, shall be paid by the seller; provided, however, that if the supplemental tests show the brick under examination to be acceptable, then the cost of such tests shall be paid by the purchaser.

SAMPLING

Standard Sample

13. The standard sample for the rattler test shall consist of ten whole undamaged brick which conform individually to the visual inspection requirements specified in Section 9.

Selection of Sample

14. (*a*) Samples shall preferably be selected at the place of manufacture and tested prior to shipment. However, in special cases where less than 100,000 brick are involved, samples, when required, may be selected subsequent to delivery at the destination.

Number of Standard Samples

(*b*) In general, one standard sample shall be selected for each 15,000 brick or fraction thereof; provided, however, that when the sampling is done at the place of manufacture prior to shipment and the total number of brick involved is more than 100,000 brick, the number of brick for which one standard sample is considered representative may be increased at the option of the purchaser to not more than 50,000 brick.

RATTLER TEST

Apparatus

15. The machine[1] used in the rattler test shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame and driving mechanism as described in Sections 16 to 20.

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[1] A detailed illustration of a rattler which will meet the requirements specified appears in Plate I of the 1936 Book of A.S.T.M. Standards, Part II, p. 128. A copy of this plate showing the construction of the machine is available from the Headquarters of the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.

Barrel

16. The barrel of the machine shall consist of the heads, headliners, staves, and staveliners conforming to the following requirements:

(*a*) *Heads.*—The heads may be cast in one piece with the trunnions which shall be $2\frac{7}{16}$ in. in diameter, and shall have a bearing 6 in. in length; or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-in. shafts and shall be key-seated for two keys, each $\frac{1}{2}$ by $\frac{3}{8}$ in. and spaced 90 deg. apart. The shaft shall be a snug fit and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ in. in the head for the driving end of the rattler and $11\frac{3}{8}$ in. for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ in.

The heads shall not be less than $\frac{3}{4}$ nor more than $\frac{7}{8}$ in. in thickness. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ in. in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ in. in thickness and extending outward $2\frac{1}{2}$ in. from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing for the staves. To secure the desired true and uniform bearing, the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge, so as to provide for two $\frac{3}{4}$-in. bolts at each end of each stave, the slots to be $\frac{13}{16}$ in. in width and $2\frac{3}{4}$ in. center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ in. in thickness extending down the outward side of the head not less than 2 in.

(*b*) *Headliners.*—There shall be for each head a cast-iron headliner, 1 in. in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ in. in diameter. This headliner shall be fastened to the head by seven $\frac{5}{8}$-in. cap screws, through the head from the outside. Whenever these headliners become worn down $\frac{1}{2}$ in. below their initial surface level, at any point of their surface, they shall be replaced with new ones. The metal of these headliners shall be hard machinery iron and should contain not less than 1 per cent of combined carbon.

(*c*) *Staves.*—The staves shall be made of 6-in. medium-carbon steel structural channels $27\frac{1}{4}$ in. in length and weighing 15.5 lb. per lineal foot. The staves shall have two holes $\frac{13}{16}$ in. in diameter, drilled in each end, the center line of the holes being 1 in. from the end and $1\frac{3}{8}$ in. either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed $\frac{5}{16}$ in.

(*d*) *Staveliners.*—The interior or flat side of each stave shall be protected by a liner $\frac{3}{8}$ in. thick by $5\frac{1}{2}$ in. wide by $19\frac{3}{4}$ in. long. The liner shall consist of medium-carbon steel plate, and shall be riveted to the channel by three $\frac{1}{2}$-in. rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 in. from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once re-riveted.

Preliminary Operation

17. When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged with 400 lb. of shot of the same sizes, and in the same proportion as provided in Section 21, and shall then be run for 18,000 revolutions at the rate of speed specified in Section 25 (*a*). The shot shall then be removed and a standard shot charge inserted after which the rattler may be charged with brick for a test.

Relining

18. No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive, but not contiguous: for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative conditions of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 in. in length, inside measurement, between headliners. The liners of the staves shall be so placed as to drop between the headliners. The staves shall be bolted tightly to the heads by four $\frac{3}{4}$-in. bolts and each bolt shall be provided with a locknut and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

Barrel Frame

19. The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

Driving Mechanism

20. The barrel shall be driven by gearing whose ratio of driver to driven is not less than one to four. The counter shaft upon which the driving pinion is mounted shall not be less than $1\frac{15}{16}$ in. in diameter, with bearing not less than 6 in. in length. If a belt drive is used, the pulley shall be not

less than 18 in. in diameter and 6½ in. in face. A belt at least 6 in. in width, properly adjusted, to avoid unnecessary slipping, should be used.

Abrasive Charge

21. The abrasive charge shall consist of cast-iron spheres of two sizes.

(*a*) *Large Spheres.*—When new, the larger spheres shall be 3.75 in. in diameter and shall weigh approximately 7.5 lb. (3.40 kg.) each. Ten spheres of this size shall be used. These shall be weighed separately after each ten tests, and if the weight of any large sphere falls to 7 lb. (3.175 kg.) it shall be discarded and a new one substituted; provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that in so far as possible the large spheres shall compose a graduated series in various stages of wear.

(*b*) *Small Spheres.*—When new, the smaller spheres shall be 1.875 in. in diameter and shall weigh approximately 0.95 lb. (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 lb. as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 in. in diameter, drilled in an iron plate ¼ in. in thickness, or weigh less than 0.75 lb. (0.34 kg.).

Further, the small spheres shall be tested by passing them over the plate mentioned or by weighing, after every ten tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres, provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

Chemical Composition of Charge

22. (*a*) The cast-iron abrasive spheres shall conform to the following requirements as to chemical composition:

Combined carbon, min., per cent	2.50
Graphitic carbon, max., per cent	0.25
Silicon, max., per cent	1.00
Manganese, max., per cent	0.50
Phosphorus, max., per cent	0.25
Sulfur, max., per cent	0.08

(*b*) For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user, before introducing the spheres into the charge, and unless the analysis conforms to the requirements specified, the batch of spheres shall be rejected.

Scales

23. The scales used shall be placed on a solid level foundation and shall be sufficiently sensitive to determine the initial weight of 10 bricks to the nearest 0.1 lb. The scale shall be tested by a standard test weight at intervals of not more than every ten tests.

Test Specimen

24. The number of brick per test shall be ten whole bricks for all weights of brick, and the brick shall be weighed to the nearest 0.1 lb. Brick shall be surface dry when tested. No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

Procedure

25. (*a*) The test shall consist of 1800 revolutions of the rattler at the rate of not less than 29.5 nor more than 30.5 r.p.m. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed ten revolutions will be allowed for starting and stopping. Only one start and stop per test is, in general, acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the percentage loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

(*b*) Any test, at the expiration of which a staveliner is found detached from the stave or seriously out of position, shall be rejected.

Percentage Loss of Weight

26. The loss shall be calculated as a percentage of the original weight of the brick composing the charge, by weighing the brick remaining in the rattler at the end of the test, deducting this weight from the original weight of the brick, dividing this difference by the original weight of the brick and multiplying by 100, as follows:

$$\text{Percentage of Loss} = \frac{\text{Original Weight} - \text{Weight after Testing}}{\text{Original Weight}} \times 100$$

In weighing the rattled brick, any piece weighing less than 1 lb. shall be rejected.

Rattler Record

27. A complete and continuous record shall be kept of the operation of all rattlers working under the rattler test. This record shall contain the following data concerning each test made:

1. The name of the person, firm or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street or contract, which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.

7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, width and thickness of the bricks.
10. The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
12. The total weight of the shot charge, after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them to conform to the requirements at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of stave liners.
15. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the counting machine.
16. Certificate of the operator as to number of stops and starts made in each test.
17. The initial collective weight of the ten brick composing the charge and their collective weight after rattling.
18. The number of broken bricks and remarks upon the portions which were included in the final weighing.
19. General remarks upon the test and any irregularities occurring in its execution.
20. The certificate of the operator that the test was made in accordance with the requirements of the American Society for Testing Materials and that the record is a true record.
21. The signature of the operator or person responsible for the test.
22. The location of the laboratory where the test was made and name of the owner.
23. The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicate, but the original record shall always be preserved intact and complete.

TENTATIVE SPECIFICATIONS
FOR
SAND-LIME BUILDING BRICK[1]
A.S.T.M. Designation: C 73 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1928; Adopted in Amended Form, 1930; Revised, 1937;
Revised and Reissued as Tentative, 1938.

Scope

1. These specifications cover brick made from sand and lime, and which are intended for use in brick masonry. Three grades of brick are covered as follows:

Grade SW.—Bricks intended for use where exposed to temperature below freezing in the presence of moisture.

Note.—As a typical example, bricks used for foundation courses and parapets in the northeastern quarter of the United States should conform to Grade SW.

Grade MW.—Bricks intended for use where exposed to temperature below freezing but unlikely to be saturated with water.

Note.—As a typical example, bricks exposed in the face of the wall other than parapet or foundations, or bricks intended for structures located in regions of the United States characterized by less severe frost action or by drier climate than is found in the northeastern quarter of the United States, should conform to Grade MW.

Grade NW.—Bricks intended for use as back-up or interior masonry; or if exposed, for use where no frost action occurs; or if frost action occurs where the average annual precipitation is less than 15 in.

Properties

2. (*a*) The bricks shall conform to the physical requirements for the grade specified, as follows:

Name of Grade	Compressive Strength (bricks flatwise), lb. per sq. in. average gross area		Modulus of Rupture (bricks flatwise), lb. per sq. in.	
	Average of Five Tests	Individual Minimum	Average of Five Tests	Individual Minimum
Grade SW	4500 or over	3500	600 or over	400
Grade MW	2500 to 4500	2000	450 or over	300
Grade NW	1500 to 2500	1500	300 or over	200

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-15 on Manufactured Masonry Units.

These specifications are in effect a revision of, and replace the former Standard Specifications for Sand-Lime Building Brick (C 73 - 37), 1937 Supplement to Book of A.S.T.M. Standards, p. 76, which standard was accordingly discontinued in 1938.

(*b*) Unless otherwise specified by the purchaser, bricks of Grades *SW* and *MW* shall be accepted in lieu of Grade *NW*, and Grade *SW* in lieu of Grade *MW*.

Test Specimens

3. For purpose of tests, bricks representative of the commercial product shall be selected by a competent person appointed by the purchaser, the place or places of selection to be designated when the purchase order is placed. The manufacturer or seller shall furnish specimens for tests without charge. All bricks shall be carefully examined and their condition noted before testing. For the purpose of tests, not less than five brick shall be required for each investigation. In general, two samples of five brick each shall be tested for each 100,000 bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, one sample of five brick from each 100,000 shall be tested. Additional representative samples may be taken at any time or place at the discretion of the purchaser.

Standard Size

4. Sand-lime brick shall conform to the following dimensional requirements within the permissible variations indicated:

	DIMENSION, IN.	PERMISSIBLE VARIATION, IN.
Depth	$2\frac{1}{4}$	$\pm\frac{1}{8}$
Width	$2\frac{3}{4}$	$\pm\frac{1}{8}$
Length	8	$\pm\frac{1}{4}$

Visual Inspection

5. All brick shall conform to the following requirements for general properties under visual inspection:

They shall be sound, of compact structure, reasonably uniform in shape and free from cracks, warpage, large pebbles, balls of clay or particles of lime that would affect their serviceability or strength.

Methods of Testing

6. The bricks shall be tested in accordance with the Standard Methods of Testing Brick (Modulus of Rupture and Compressive Strength) (A.S.T.M. Designation: C 67) of the American Society for Testing Materials.[1]

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 78.

TENTATIVE SPECIFICATIONS
FOR
STRUCTURAL CLAY LOAD-BEARING WALL TILE[1]

A.S.T.M. Designation: C 34 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the strength and absorption properties and the general requirements of structural clay load-bearing wall tile made from surface clay, shale, fireclay, or admixtures thereof. If tile having a particular color, texture or finish is desired by the purchaser, such features shall be covered by separate specifications.

Classification

2. (*a*) According to results of physical tests, the tile shall be classified as *LB X* and *LB* on the basis of the following absorption and compressive strength requirements:

Use	Designation	Absorption, per cent			Compressive Strength (Based on Gross Area),[a] lb. per sq. in.			
					End-Construction Tile		Side-Construction Tile	
		Average of Five Tests	Individual Maximum	Individual Minimum	Average of Five Tests	Individual Minimum	Average of Five Tests	Individual Minimum
Not restricted[b].........	Class *LB X*	5 to 16	19	4	1400 or more	1000	700 or more	500
Where not exposed to frost action[c].........	Class *LB*...	5 to 25	28	4	1000 or more	700	700 or more	500

[a] The gross area of a unit shall be the total area including cells of a section perpendicular to the direction of loading. Re-entrant spaces are included in the gross area, unless these spaces are to be occupied in masonry by portions of adjacent units.

[b] Tile classed as *LB X* may be considered to be suitable for general use in masonry construction and to be adapted for use in masonry exposed to weathering provided they are burned to the normal maturity for the clay. They may also be considered suitable for the direct application of stucco.

[c] Tile classed as *LB* may be considered as being suitable for general use in masonry where not exposed to frost action or for use in exposed masonry where protected with a facing of 3 in. or more of stone, brick, terra cotta, or other masonry.

(*b*) The range in absorption percentage for tile delivered to any one job shall be not more than 12.

(*c*) Tile classed as *LB X* shall be accepted under all conditions in lieu of tile classed as *LB*.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-15 on Manufactured Masonry Units.

These tentative specifications are in effect a tentative revision of, and will supersede when adopted as standard, the present Standard Specifications for Structural Clay Load-Bearing Wall Tile (C 34 - 36), 1936 Book of A.S.T.M. Standards, Part II, p. 172.

(*d*) End-construction tile are tile which are placed in the wall with axes of the cells vertical. Side-construction tile are tile which are placed in the wall with the axes of the cells horizontal. Where end-construction tile are used on the side they shall conform to the requirements of side-construction tile and *vice versa*.

(*e*) Bonding tile shall be so designed as to provide recesses for header brick courses when laid up in brick-faced walls.

Number of Cells

3. (*a*) Load-bearing tile shall conform to the following requirements as to minimum number of cells[a] in the direction of wall thickness:

NOMINAL HORIZONTAL THICKNESS OF TILE AS LAID IN WALL, IN.	MINIMUM NUMBER OF CELLS[a] IN DIRECTION OF WALL THICKNESS
4	1
6	2
8	2
10	2
12	3

---

[a] Cells, as used in this section, are hollow spaces enclosed within the perimeter of the exterior shells, and having a minimum dimension of not less than $\frac{1}{2}$ in. and a cross-sectional area of not less than 1 sq. in.

(*b*) In double-shell tile the two voids between exterior and interior shells on either side of the tile shall be considered as one cell in thickness of wall when their combined width is not less than $\frac{1}{2}$ in., provided the short webs between the inner and outer shells are not greater in number or thickness than the long transverse webs holding the inner shells.

(*c*) Re-entrant spaces not less than 1 in. in depth and not less than 1 sq. in. in area, which form cells when the units are laid in the walls, shall be considered as cells in the direction of wall thickness, but not in the units.

Shell and Web Thickness

4. (*a*) The average over-all thickness of the shells, measured between the inner and extreme outer surfaces of end-construction load-bearing tile, shall be not less than $\frac{3}{4}$ in., except that in double-shell tile the combined average over-all thickness of the inner and outer shell shall be not less than $\frac{3}{4}$ in. The thickness of the webs shall be not less than $\frac{1}{2}$ in.

(*b*) The average over-all thickness of the shells, measured between the inner and extreme outer surfaces of side-construction load-bearing tile, shall be not less than $\frac{5}{8}$ in., except that in double-shell tile the combined average over-all thickness of the inner and outer shell shall be not less than $\frac{3}{4}$ in. The thickness of the webs shall be not less than $\frac{1}{2}$ in.

(*c*) The width of any cell in side-construction tile, measured in the direction of wall thickness, shall not exceed four and one half times the average over-all thickness of either the upper or lower bearing shells.

Permissible Variations in Dimensions

5. The thickness of bonding and other types of tile manufactured for use in combination with brick or other materials may vary from the nominal thicknesses indicated in Section 3, as required by construction requirements. No over-all dimension shall vary more than 3 per cent over or under the specified dimension for any form or size of unit.

Color

6. Color of tile varies with the type of clay used and degree of burning; hence, it cannot be taken as indicative of classification until after it has been related to absorption and strength by actual tests.

Workmanship

7. All tile shall be free from laminations and from such cracks, blisters, surface roughness, and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

Scoring

8. Surfaces of all tile intended for the direct application of plaster or stucco shall be scratched or scored. When scored, each groove shall be not less than $\frac{1}{8}$ in. nor more than $\frac{1}{4}$ in. in depth, nor more than 1 in. in width. The area covered by the grooves shall not exceed 50 per cent of the area of the scored faces.

Marking

9. All load-bearing tile shall bear the word "Load-Bearing," or "*LB X*" or "*LB*," and the name, initials or trade-mark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

Inspection

10. The purchaser or his authorized representative shall be accorded proper facilities for sampling and inspection of units both at the factory and at the site of the work. At least 10 days from the time of sampling should be allowed for completion of the tests.

Rejection

11. Tile shall be rejected for failure to meet the requirements for shell and web thicknesses, number of cells, specified size, workmanship, and finish. In case of failure to meet the requirements for the class specified, the manufacturer may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. In case the second set of samples fails to meet the requirements the entire lot shall be rejected.

Expense of Tests

12. Except as specified in Section 11 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Methods of Testing

13. Tile shall be sampled and tested in accordance with the Standard Methods of Sampling and Testing Structural Clay Tile (A.S.T.M. Designation: C 112) of the American Society for Testing Materials.[1]

EXPLANATORY NOTE

The following average weights of structural clay load-bearing wall tile are given for the information of structural designers and other interested parties:

NOMINAL HORIZONTAL THICKNESS OF TILE AS LAID IN WALL, IN.	AVERAGE WEIGHT, LB. PER SQ. FT. OF TILE[a]
4	20
6	30
8	36
10	42
12	52

[a] The weights given in the above table are for scored tile. If any of the faces are not scored, the weights are increased 1 lb. per sq. ft. of unscored area.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 183.

Tentative Specifications for

HOLLOW NON-LOAD-BEARING CONCRETE MASONRY UNITS[1]

A.S.T.M. Designation: C 129 - 38 T

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. These specifications cover the strength, moisture content, and general requirements of hollow non-load-bearing concrete masonry units made from portland cement and suitable aggregates such as sand, gravel, crushed stone, bituminous or anthracite cinders, burned clay or shale, and blast-furnace slag. If a particular surface texture, finish, or uniformity of color is required, it shall be as specified in the purchase order.

Compressive Strength

2. The average compressive strength of five units at the time of delivery to the site shall be not less than the following:

	MEAN OF FIVE TESTS	INDIVIDUAL MINIMUM
Compressive strength, based on gross area, lb. per sq. in......	350 or over	300

Moisture Content

3. The average percentage of moisture in the units at time of sampling shall not exceed 40 per cent of the total absorption of the units.

Dimensions and Permissible Variations

4. (*a*) No over-all dimension shall vary more than 3 per cent over or under the specified dimension for any form or size of unit.

(*b*) Minimum face shell thickness shall be not less than $\frac{1}{2}$ in.

Materials, Workmanship and Finish

5. (*a*) Units shall contain no materials which will stain plaster applied thereto. The combustible content present in cinder aggregate shall not exceed 35 per cent of the weight of the aggregate.

(*b*) All units shall be sound and free from cracks or defects that would interfere with the proper placing of the unit.

(*c*) Units which are intended to serve as a base for plaster or stucco shall have a sufficiently rough surface to give good bond.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-15 on Manufactured Masonry Units.

Marking

6. All units shall bear a distinctive mark of the manufacturer or shall be otherwise readily identified as to origin.

Inspection

7. The samples may be taken either at the site of the work or at the place of manufacture. The purchaser or his authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery. At least 10 days shall be allowed for completion of the tests.

Rejection

8. Individual units shall be rejected for failure to meet size, finish, workmanship, or materials requirements. In case of failure to meet the strength or moisture content requirements, the manufacturer may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. In case the second set of samples fails to meet the test requirements, the entire lot shall be rejected.

Expense of Tests

9. Except as specified in Section 8 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Methods of Testing

10. Units shall be sampled and tested in accordance with the Tentative Methods of Sampling and Testing Concrete Masonry Units (A.S.T.M. Designation: C 140) of the American Society for Testing Materials.[2]

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[2] See p. 787.

TENTATIVE SPECIFICATIONS

FOR

CONCRETE MASONRY UNITS FOR USE IN CONSTRUCTION OF CATCH BASINS AND MANHOLES[1]

A.S.T.M. Designation: C 139 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the strength and absorption properties, and general requirements of solid, precast, segmental concrete masonry units made from portland cement and suitable aggregates such as sand, gravel, crushed stone, and air-cooled blast-furnace slag.

Compressive Strength

2. The average compressive strength of five units at the time of delivery to the site shall be not less than the following:

	MEAN OF FIVE TESTS	INDIVIDUAL MINIMUM
Compressive strength (based on gross area), lb. per sq. in.	2500 or over	2000

Absorption

3. The absorption of water shall be not more than 8 per cent of the dry weight of the units. No individual unit shall absorb more water than 10 per cent of its dry weight.

Dimensions and Permissible Variations

4. (*a*) The thickness of unit shall be not less than 5 in.

(*b*) No over-all dimension shall vary more than 3 per cent over or under the specified dimension for any form or size of unit.

Workmanship

5. All units shall be sound and free from cracks or other defects that would interfere with the proper placing of the unit.

Marking

6. All units shall bear a distinctive mark of the manufacturer or shall be otherwise readily identified as to origin.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-15 on Manufactured Masonry Units.

Inspection

7. The purchaser or his authorized representative shall be accorded proper facilities to inspect and sample the units at the factory from lots ready for delivery. At least 10 days shall be allowed for completion of the tests.

Rejection

8. Individual units shall be rejected for failure to meet the size, workmanship or materials requirements. In case of failure to meet the strength or absorption requirements, the manufacturer may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. In case the second set of samples fails to meet the test requirements, the entire lot shall be rejected.

Expense of Tests

9. Except as specified in Section 8 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Methods of Testing

10. Units shall be sampled and tested in accordance with the Tentative Methods of Sampling and Testing Concrete Masonry Units (A.S.T.M. Designation: C 140 – 38 T) of the American Society for Testing Materials.[1]

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[1] See p. 787.

TENTATIVE METHODS OF SAMPLING AND TESTING CONCRETE MASONRY UNITS[1]

A.S.T.M. Designation: C 140 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

SAMPLING

Selection of Samples for Test

1. Samples of full-size units for testing shall be selected and tested by the purchaser or by his authorized representative. If samples are selected at the site of the work, units for moisture content tests shall be taken within 48 hr. after delivery. Samples shall be representative of the whole lot of units from which they are selected.

Number of Samples

2. For the strength, absorption, and moisture content determinations, ten individual units shall be selected from each lot of 10,000 units, or fraction thereof; 20 individual units from each lot of more than 10,000 and less than 100,000 units. For lots of more than 100,000 units ten individual units shall be selected from each 50,000 units, or fraction thereof, contained in the lot.

Marking Samples

3. All units selected for purpose of tests shall be permanently identified, and where a moisture content test is required the units shall be weighed, before shipment to the laboratory.

COMPRESSIVE STRENGTH TESTS

Number of Tests

4. Five full-size units shall be used.

Position of Units

5. All units shall be tested in a position such that the load is applied in the same direction as in service.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee C-15 on Manufactured Masonry Units.

These methods are intended to supersede the testing procedures in the Standard Specifications and Tests for Load-Bearing Concrete Masonry Units (C 90 - 36), 1936 Book of A.S.T.M. Standards, Part II, p. 168; and the Tentative Specifications and Methods of Test for Concrete Units for Non-Load-Bearing Masonry (C 129 - 37 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 752 (1937); also 1937 Book of A.S.T.M. Tentative Standards, p. 511.

Capping

6. (*a*) A quantity of plastic capping mortar made of one part (by volume) of portland cement and one part of calcined gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plane surface which has been coated with oil. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be firmly pressed down with a single motion.

(*b*) The average thickness of the cap after the extruded capping mortar has been removed and the edges trued shall be not more than $\frac{1}{8}$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced.

Time of Testing

(*c*) The cap shall be aged at least 6 hr. before the unit is tested.

Bearing Block

7. A spherical bearing block having a minimum diameter of 6 in. and meeting the general requirements specified in Section 5 (*b*) of the Tentative Method of Test for Compressive Strength of Portland-Cement Mortars (A.S.T.M. Designation: C 109 – 37 T) of the American Society for Testing Materials,[1] shall be used. When the bearing area of the spherical bearing block is not sufficient to cover the area of the specimen, *a steel* plate whose surfaces have been machined to a true plane within plus or minus 0.001 in., and with a thickness equal to at least one-third of the distance from the edge of the spherical bearing to the most distant corner shall be placed between the spherical bearing block and the capped specimen.

Speed of Testing Machine

8. The speed of the moving head of the testing machine shall not be more than 0.05 in. per min.

Calculations

9. (*a*) *Compressive Strength.*—The compressive strength of a unit shall be the maximum load in pounds applied divided by the gross cross-sectional area in square inches.

(*b*) *Gross Area.*—The gross cross-sectional area of a unit is the total area of a section, perpendicular to the direction of the load, including areas within cells and within re-entrant spaces, unless those spaces are to be occupied by adjacent masonry.

(*c*) *Net Area.*—The average percentage of net area of the unit is equal to the net volume divided by the gross volume and multiplied by 100.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 726 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 476.

$$\text{Net area, per cent} = \frac{\text{Net volume} \times 100}{\text{Gross volume}}$$

$$\text{Net volume, cubic feet} = \frac{\text{Dry weight of unit}}{\text{Weight per cubic foot}}$$

$$\text{Gross volume, cubic feet} = \frac{T \times H \times L}{1728}$$

$$\text{Weight per cubic foot, lb.} = \frac{\text{Dry weight} \times 62.4}{\text{Wet weight} - \text{Suspended immersion weight}}$$

where T = the thickness of the unit in inches,
H = the height of the unit in inches, and
L = the length of the unit in inches.

ABSORPTION TESTS

Selection of Test Samples

10. Five full-size units shall be used.

Marking Test Samples

11. Each unit shall be marked so that it may be identified at any time. Markings shall not cover more than 5 per cent of the total superficial area of the unit.

Accuracy of Weighings

12. The balance used shall be accurate to within 0.5 per cent of the weight of the unit.

Saturation of Samples

13. The samples shall be completely immersed in water at room temperature at from 15.6 to 26.7 C. (60 to 80 F.) for 24 hr. The samples shall then be weighed while suspended with a metal wire and completely submerged in water. They shall be removed from the water and allowed to drain for 1 min. by placing on a $\frac{3}{8}$-in. or coarser wire mesh, visible surface water being removed with a damp cloth, and immediately weighed.

Drying Test Samples

14. Subsequent to saturation all samples shall be dried in a drier or oven at a temperature between 100 and 115 C. (212 and 239 F.) and weighed at 24-hr. intervals until the loss in weight does not exceed 1 per cent in a 24-hr. period.

Calculations

15. (*a*) *Absorption.*—The absorption in pounds per cubic foot of concrete is equal to 62.4 times the difference between the wet and dry weights divided by the difference between the wet and suspended immersion weights, as follows:

$$\text{Absorption, lb. per cu. ft.} = \frac{(\text{Wet weight} - \text{Dry weight}) \times 62.4}{(\text{Wet weight} - \text{Suspended immersion weight})}$$

The absorption expressed as a percentage of the dry weight is equal to the difference between the wet and dry weights divided by the dry weight and multiplied by 100, as follows:

$$\text{Absorption, per cent} = \frac{(\text{Wet weight} - \text{Dry weight}) \times 100}{\text{Dry weight}}$$

(*b*) *Moisture Content.*—The moisture content of the units at time of sampling (expressed as a percentage of the total absorption) is the difference between the average weight as sampled and the average dry weight divided by the difference between the average wet weight and the average dry weight and multiplied by 100.

$$\text{Moisture content, per cent} = \frac{(\text{Sampled weight} - \text{Dry weight}) \times 100}{(\text{Wet weight} - \text{Dry weight})}$$

TENTATIVE METHODS OF TEST
FOR
SIZE, WARPAGE, AND BULK SPECIFIC GRAVITY OF REFRACTORY BRICK[1]

A.S.T.M. Designation: C 134 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These methods cover the procedure for measuring the dimensions of refractory brick and tile and for determining the warpage of refractory tile.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Rule.*—A hooked steel rule, graduated in 0.01 in. ($\frac{1}{64}$ in.) with a right-angle piece on one end to fix the zero point of the scale against one face of the brick or tile.

(*b*) *Measuring Wedge.*—A steel wedge, 2.5 in. in length by 0.5 in. in width by 0.5 in. in thickness at one end, and tapered, starting at a line 0.5 in. from one end to zero thickness at the other end. The wedge shall be graduated and numbered to show the thickness of the wedge, between the base AB and the slope AC, in thirty-seconds of an inch, as illustrated in Fig. 1 (*b*).

(*c*) *Scale.*—Weighing machine reading to at least 0.02 lb.

Preparation of Specimens

3. Ten specimens shall be taken to constitute a sample. Any pimples or feather edges on the specimens which would fall under the hook of the rule, or under the wedge shall be removed by lightly rubbing two specimens together.

Measurements

4. (*a*) Measurements for dimensions of rectangular specimens shall be taken across the middle of each of the faces and recorded to the nearest 0.01 in. (or $\frac{1}{64}$ in.). The length and width measurements shall be taken across both faces of largest area, and the thickness across the middle of the edges The position of the rule in three of the six positions is shown in Fig. 1 (*a*).

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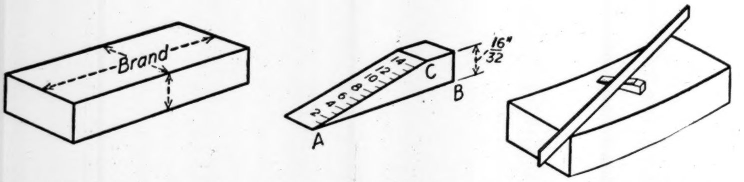
[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee C-8 on Refractories.

(*b*) The specimen shall be weighed to the nearest 0.02 lb. (0.25 oz.).

(*c*) *Warpage.*—The warpage shall be measured on the concave side only and shall be obtained by placing a steel straightedge across each diagonal of the refractory tile and inserting between it and the tile the measuring wedge, as illustrated in Fig. 1 (*c*).



(*a*) Method of Measuring Brick. (*b*) Measuring Wedge. (*c*) Method of Measuring Warpage.

FIG. 1.—Method of Measuring Refractory Brick and Tile.

Report

5. (*a*) The averaged length, width, and thickness as obtained from the pairs of readings on parallel faces of the specimen shall be calculated, and the average length, width, and thickness of the 10 specimens shall be reported as the dimensions of the lot.

(*b*) The bulk specific gravity of the specimen shall be calculated as follows:

$$\text{Bulk specific gravity} = \frac{\text{Weight in pounds} \times 27.7}{\text{Volume in cubic inches}}$$

The average bulk specific gravity of the 10 specimens shall be reported as the bulk specific gravity of the lot.

(*c*) The warpage of the specimens shall be calculated by dividing the total warpage in thirty-seconds of an inch, as measured by the wedge, by the length of the diagonal in feet, and the average warpage of the 10 specimens shall be reported in thirty-seconds of an inch per foot as the warpage of the lot.

TENTATIVE METHOD OF TEST
FOR
TRUE SPECIFIC GRAVITY OF BURNED REFRACTORY MATERIALS[1]

A.S.T.M. Designation: C 135 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method of test is intended for the determination of true specific gravity of refractory materials under prescribed conditions.

NOTE.—This method is not applicable to materials attacked by water.

Apparatus

2. The apparatus shall consist of the following: Analytical balance and weights, 50-ml. pycnometer bottle with capillary tube stopper, thermometer, drying oven, weighing bottle, desiccator, a suitable apparatus to produce a vacuum of 0.5 to 1.0-in. mercury pressure, and distilled water at room temperature.

Test Specimens

3. (*a*) The test specimen shall consist of two walnut-size pieces cut from different positions in the specimen in such a way as to exclude all skin surfaces. If an average specific gravity is desired, at least five specimens shall be tested.

(*b*) The specimen shall be crushed, if necessary, between hardened steel surfaces and then ground in an agate mortar, either by hand or by a mechanical sample grinder[2] so constructed as to prevent the introduction of any impurity. The specimen shall then be reduced to a 50-g. sample by quartering in the standard manner. Any magnetic material introduced by crushing or grinding shall be removed by means of a magnet. The entire 50-g. sample shall be ground in an agate mortar so that it will pass a No. 100 A.S.T.M. sieve[3] (equivalent to Tyler standard series, mesh No. 100). Care shall be taken at all stages of the grinding and quartering not to exclude any portions which are difficult to grind, that is, all selective sample preparation shall be avoided.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-8 on Refractories.

[2] The McKenna, Carling, Fisher, or similar type sample grinders are satisfactory for this purpose.

[3] For detailed requirements of this sieve, see the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, p. 1289.

Procedure

4. (*a*) The 50-g. sample shall be dried to constant weight at 110 C. and placed in a glass-stoppered weighing bottle. Duplicate tests shall be made on material from the 50-g. sample. All weights shall be recorded to the nearest 0.0001 g.

(*b*) The pycnometer and stopper shall be dried at 110 C., cooled in a desiccator, weighed on an analytical balance, and the weight recorded as weight, p. The pycnometer shall then be filled with distilled water at room temperature, t, and again weighed with the stopper in place, recording the weight as W_1. The pycnometer shall then be emptied and again dried.

(*c*) Approximately 8 to 12 g. of the sample shall be placed in the dry pycnometer; the pycnometer, stopper, and sample weighed and the weight recorded as weight, W. The bottle shall next be filled to approximately one-half its capacity with distilled water at room temperature, t. The sample and water shall be very thoroughly mixed by stirring with a glass rod and evacuated at 0.5 to 1.0-in. mercury pressure to remove entrapped air. A suitable method of evacuation is described in Section 6 of the Standard Methods of Test for Specific Gravity of Pigments (A.S.T.M. Designation: D 153) of the American Society for Testing Materials.[1]

(*d*) After evacuation, the bottle shall be filled with distilled water at room temperature, t, and the excess water on the tip of the capillary removed by filter paper. The pycnometer and contents shall then be weighed, and the weight recorded as weight W_2.

Calculation

5. (*a*) The true specific gravity shall be calculated in accordance with the following formula:

$$\text{Sp. gr., } t \text{ C.}/t \text{ C.} = \frac{W - p}{(W - p) - (W_2 - W_1)}$$

where t C. = the temperature of the material and the water,
p = the weight of the stoppered pycnometer,
W = the weight of the stoppered pycnometer and sample,
W_1 = the weight of the stoppered pycnometer filled with water, and
W_2 = the weight of the stoppered pycnometer, sample, and water.

(*b*) The true density of the sample may be determined without additional measurement in accordance with the following formula:

$$\text{True density} = \text{Sp. gr.} \times (d_w - d_a)$$

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 638.

where d_w = the density of water at the temperature at which the test was made, and

d_a = the density of air at the temperature at which the test was made.[1]

Precision

6. Both determinations shall be reported to the nearest 0.001, and they shall check to within 0.005, or additional determinations shall be made.

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[1] Values of $(dw - da)$ for temperature from 15 to 30 C. are given in Table 35, Standard Density and Volumetric Tables, National Bureau of Standards, *Circular No. 19*, p. 52.

TENTATIVE SPECIFICATIONS
FOR
CONCRETE IRRIGATION PIPE[1]

A.S.T.M. Designation: C 118 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

Scope

1. These specifications cover concrete pipe intended to be used for conveying irrigation water under low hydrostatic heads.

Class

2. Pipe manufactured according to these specifications shall be known as "Standard Concrete Irrigation Pipe."

Basis of Acceptance

3. The acceptability of the pipe shall be determined by the tests prescribed in these specifications, if and when required, and by inspection to determine whether the pipe conforms to these specifications in design and freedom from defects.

MATERIALS

Concrete

4. The concrete shall consist of portland cement, mineral aggregates and water.

Cement

5. Portland cement shall conform to the requirements of the Standard Specifications for Portland Cement (A.S.T.M. Designation: C 9),[2] or the Standard Specifications for High-Early Strength Portland Cement (A.S.T.M. Designation: C 74)[2] of the American Society for Testing Materials.

Aggregates

6. Aggregates shall conform to the requirements of the Tentative Specifications for Concrete Aggregates (A.S.T.M. Designation: C 33 - 37 T) of the American Society for Testing Materials.[3] The maximum size of

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-13 on Concrete Pipe.

[2] 1938 Supplement to Book of A.S.T.M. Standards, pp 95 and 97.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 792 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 620.

coarse aggregate used shall not exceed one-third the shell thickness of the pipe.

Mixture

7. The aggregates shall be so graded and proportioned and thoroughly mixed with such proportions of cement and water as will produce a homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of these specifications.

DESIGN AND PERMISSIBLE VARIATIONS IN DIMENSIONS

Alternative Design

8. Manufacturers may submit to the purchaser, for approval, designs other than those given in Table I. In no alternative design, however, shall the shell thickness and test requirements be less than those given in Table I.

Variation in Diameter

9. Variation of the internal diameter shall not exceed plus or minus $\frac{3}{16}$ in. for 6-in. pipe, plus or minus $\frac{1}{4}$ in. for pipe having an internal diameter greater than 6 in. but not more than 18 in., and plus or minus $\frac{5}{16}$ in. for larger pipe.

Variation in Thickness

10. The shell thickness at any point shall not be less than the minimum specified in Table I by more than $\frac{1}{16}$ in. for pipe having an internal diameter of 12 in. or less, $\frac{3}{32}$ in. for pipe having an internal diameter greater than 12 in. but not more than 18 in., and $\frac{1}{8}$ in. for larger pipe.

Joints

11. The ends of concrete irrigation pipe shall be so formed that when the pipe are laid together and the joints cemented they will make a continuous and uniform line of pipe with a smooth and regular interior surface. The joint shall be of such design as will permit effective cementing and placement without appreciable irregularities in the flow line.

PHYSICAL TESTS

Test Specimens

12. (*a*) Specimens for tests shall be full size pipe which shall in every respect conform to the inspection requirements prescribed in these specifications.

(*b*) The specimens to be tested shall be selected at random by the purchaser or his representative at the point or points specified when placing the order. The manufacturer shall furnish for purpose of tests, without charge, up to 0.5 per cent of the number of pipe of each size included in the order, except that in no case shall less than two specimens be furnished, the manufacturer bearing all expense of testing such pipe. Should a larger number of specimens be tested upon demand of the purchaser or manufacturer, then the cost of such additional test specimens and the expense of testing shall be borne by the party making such demand.

(*c*) The purchaser shall specify the proportion of the test specimens that shall be subjected to the load tests and the proportion that shall be subjected to the hydrostatic test.

(*d*) Should the test specimens selected by the purchaser conform to the test requirements, then all pipe represented by such specimens shall be accepted, provided the pipe shall otherwise conform to the specifications.

(*e*) Should any of the specimens first tested fail to conform to the test requirements, then the manufacturer shall have the right to test two additional lengths of pipe from the same lot, selected by mutual agreement with the purchaser, for each specimen that has failed. If the additional pipe so tested all conform to the test requirements, then all pipe represented by such tests shall be accepted, otherwise they shall be subject to rejection.

TABLE I.—REQUIREMENTS FOR STANDARD CONCRETE IRRIGATION PIPE.

Internal Diameter, in.	Minimum Shell Thickness, in.	Test Requirements		
		Internal Hydrostatic Pressure on Individual Sections, lb. per sq. in.	Minimum Three-Edge-Bearing Load, lb. per linear ft.	Maximum Absorption, per cent
*6	$\frac{3}{4}$	75	1000	8
8	$\frac{7}{8}$	65	1000	8
10	1	60	1250	8
12	$1\frac{1}{8}$	55	1500	8
*14	$1\frac{1}{4}$	50	1600	8
15	$1\frac{3}{8}$	50	1700	8
*16	$1\frac{3}{8}$	50	1800	8
18	$1\frac{1}{2}$	50	1900	8
*20	$1\frac{7}{8}$	45	2000	8
21	2	45	2100	8
24	$2\frac{1}{8}$	40	2200	8

* Special sizes obtainable in some localities.

Load Test

13. Pipe shall be tested for strength by either the three-edge-bearing method or the sand-bearing method.

Three-Edge-Bearing Method

(*a*) When tested by the three-edge-bearing method (see Fig. 1), individual pipe shall meet the minimum load requirements specified in Table I.

In making the test the ends of each specimen of pipe shall be accurately marked in halves of the circumference prior to the test. The two lower bearings shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately $\frac{1}{2}$ in. The strips shall be straight and shall be securely fastened to a rigid block at least 6 by 6 in. in cross section. The interior vertical sides of the strips shall be parallel and a distance apart of 1 in. per ft. of pipe diameter, but in no case less than 1 in. If requested by the manufacturer or purchaser previous to the test, before the pipe is placed, a fillet of plaster of Paris and sand, thick enough to compensate for the inequalities of the pipe barrel, shall be cast on the surface of the lower bearing. The pipe shall be placed upon the fillet while the plaster of Paris is still somewhat plastic. The upper bearing shall be a rigid wooden block at least 6 by 6 in. in cross section, straight and true from end to end. A fillet of plaster of Paris may also be cast along the length of the crown of the pipe to equalize the bearing. The upper bearing shall be brought in contact while the plaster of Paris is somewhat plastic. The upper and lower bearings shall extend the full length of the pipe (see Fig. 1).

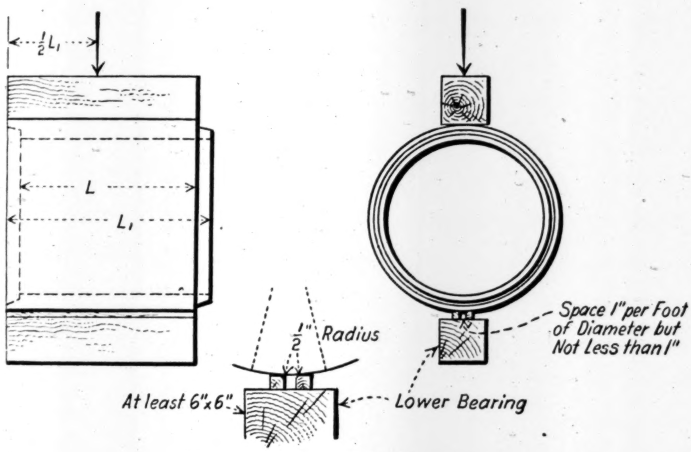


FIG. 1.—Three-Edge Bearings.

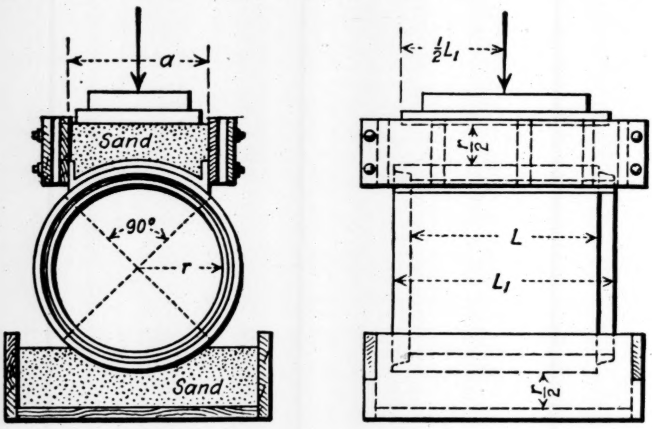
Sand-Bearing Method

(*b*) When tested by the sand-bearing method (see Fig. 2) individual pipe shall meet a minimum load 50 per cent greater than specified in Table I for the three-edge-bearing test.

When the sand-bearing method is used (see Fig. 2) the ends of each specimen of pipe shall be accurately marked in quarters of the circumference prior to the test. Specimens shall be carefully bedded in sand, above and below, for one-fourth the circumference of the pipe, measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean and shall contain not less than 5 per cent of moisture, and shall be such as will pass a 4760-micron (No. 4) sieve. The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come into contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck off level with a straight edge, and shall be covered with a rigid top-bearing plate having its lower surface in a true plane, made of heavy timbers or other rigid material and capable of distributing the test load uniformly and without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate; provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.



Bedding of Barrel.

FIG. 2.—Sand Bearings.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may be attached, if desired, to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Testing Apparatus

(*c*) In making the test, any mechanical or hand-power device may be used in which the head that applies the load moves at such a speed as to increase the load at a uniform rate of approximately 2000 lb. per linear foot of pipe per minute.

It is necessary that the testing machine used for the strength tests shall produce a uniform deflection throughout the full length of the pipe. The testing machine shall be substantial and rigid throughout, so that the distribution of the loads will not be affected appreciably by the deformation or yielding of any part.

The load shall be applied continuously until the required strength of the pipe specified in Table I is reached. The load per linear foot of pipe shall be calculated by dividing the total recorded load by the laying length. The pipe shall not be allowed to stand under load longer than is required to apply the load and to observe and record it. The pipe shall be surface-dry when tested.

Hydrostatic Test

14. (*a*) When an individual pipe is subjected to the internal hydrostatic pressure given in Table I, there shall be no leakage through the shell of the pipe. Moisture appearing on the surface of the pipe in the form of patches or beads adhering to the surface shall not be considered leakage.

(*b*) The equipment for making the hydrostatic test shall be mutually satisfactory to the purchaser and the manufacturer. Suitable fittings shall be provided for exhausting the air and admitting the water into the specimen. A standardized pressure gage for recording the internal pressure shall be connected close to the specimen. The pressure shall first be increased uniformly to 10 lb. per sq. in. and held at this pressure for 10 min. The water pressure shall then be increased uniformly until the required maximum pressure is reached as specified in Table I. If the pipe is to be coated on the inside with cement grout or other material, the hydrostatic test shall be made before such coating is applied.

Absorption Test

15. Absorption tests shall be made in accordance with the procedure described in the following Paragraphs (*a*) to (*e*):

(*a*) *Test Specimens.*—The number of absorption test specimens shall be equal to the number of pipe provided for testing. The specimens shall be obtained from pipe that are acceptable as to strength, and shall be taken from pipe used in making the strength test after that test is made. The specimens shall be marked with the number or identification mark of the pipe from which they were taken. Each specimen shall have an area of 12 to 20 sq. in., as measured on one surface of the pipe, and a thickness equal to the full depth of the pipe shell, and shall be free from visible cracks.

(*b*) *Drying Specimens.*—Specimens shall be dried at a temperature not to exceed 230 F. (110 C.) until two successive weighings at intervals of not less than 2 hr. show an increment of loss not greater than 0.1 per cent of the original weight of the specimen.

(*c*) *Immersion and Reweighing.*—The dried specimens shall be placed in a suitable receptacle covered with distilled water or rain water, raised to the boiling point and boiled for 5 hr., and then cooled in water to a final temperature of from 59 to 68 F. (15 to 20 C.). When cool, the specimens shall be removed from the water and allowed to drain for not more than 1 min. The superficial water shall then be removed by a towel or blotting paper, and the specimens immediately weighed.

(*d*) *Weighing Devices.*—The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same degree of accuracy shall be obtained.

(*e*) *Calculation and Reporting of Results.*—The increase in weight of the boiled specimen over its dry weight shall be taken as the absorption of the specimen, and shall be expressed as a percentage of the dry weight. The results shall be reported separately for each specimen.

WORKMANSHIP AND FINISH

Finish

16. Pipe shall be concentric, and free from fractures, large or deep cracks and surface roughness, other than those normally produced in the manufacture of the pipe. The planes of the ends of the pipe shall be perpendicular to the longitudinal axis.

INSPECTION AND REJECTION

Age for Shipment

17. Pipe shall be considered ready for acceptance when they conform to the test requirements prescribed in these specifications, and have been properly cured for at least 7 days.

Inspection

18. The quality of all materials and the finished pipe shall be subject to inspection and approval by an inspector employed by the purchaser.

Causes for Rejection

19. Pipe shall be subject to rejection on account of failure to conform to any of the specification requirements or on account of any of the following:

(*a*) Fractures or cracks passing through the shell, except that an end crack that does not exceed the depth of the joint, or a fracture that at its deepest point does not exceed the depth of the joint nor extend more than 10 per cent around the circumference of the joint shall not be considered cause for rejection unless these defects exist in more than 5 per cent of the pipe inspected. If these defects exist in more than 5 per cent of the pipe inspected, the defective pipe shall be rejected.

(*b*) Defects which indicate imperfect mixing, placing and curing of concrete.

(*c*) The absence of distinct web-like markings on the external surface of pipe made by the packerhead or machine-tamped process.

TENTATIVE METHOD OF TEST
FOR
ABRASION OF COARSE AGGREGATE BY USE OF THE LOS ANGELES MACHINE[1]

A.S.T.M. Designation: C 131 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.[2]

Scope

1. This method of test is intended for determining the abrasive resistance of crushed rock, crushed slag, uncrushed gravel, and crushed gravel (Note).

NOTE.—Ledge rock, hand-broken into approximately cubical fragments of the different sizes shown, when tested by this method, has been found to have a loss of approximately 85 per cent of that for crushed rock of the same quality.

Los Angeles Machine

2. The Los Angeles abrasion testing machine, conforming in all its essential characteristics to the design shown in Fig. 1, shall be used. The machine shall consist of a hollow steel cylinder, closed at both ends, having an inside diameter of 28 in. and an inside length of 20 in. The cylinder shall be mounted on stub shafts attached to the ends of the cylinder, but not entering it, and mounted in such a manner that it may be rotated about its axis in a horizontal position. An opening in the cylinder shall be provided for the introduction of the test sample. The opening shall be closed dust-tight with a removable cover bolted in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface. A removable steel shelf, projecting radially $3\frac{1}{2}$ in. into the cylinder and extending its full length, shall be mounted along one element of the interior surface of the cylinder. The shelf shall be of such thickness and so mounted, by bolts or other approved means, as to be firm and rigid. The position of the shelf shall be such that the distance from the shelf to the opening, measured along the circumference of the cylinder in the direction of rotation, shall not be less than 50 in.

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[1] Under the standardization procedure of the Society, this method is under the joint jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates and Committee D-4 on Road and Paving Materials.

[2] Revision accepted by Committee E-10 on Standards, August 25, 1938.

NOTE.—The use of a shelf of wear-resistant steel, rectangular in cross-section and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the charge will be caught on the outside face of the angle.

Abrasive Charge

3. (*a*) The abrasive charge shall consist of cast-iron spheres or steel spheres approximately $1\frac{7}{8}$ in. in diameter and weighing between 390 and 445 g. each. The cast-iron spheres shall conform to the following requirements as to chemical composition:[1]

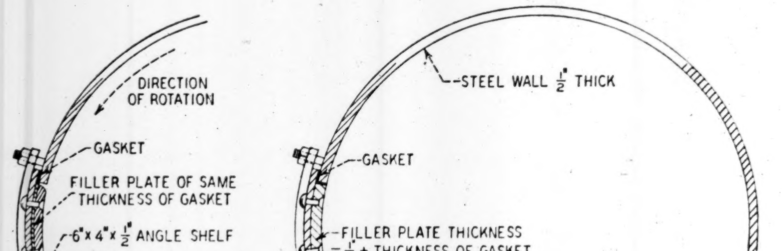
DIRECTION OF ROTATION
GASKET
FILLER PLATE OF SAME THICKNESS OF GASKET
6" x 4" x ½" ANGLE SHELF
3½"
7½" x ¼" PLATE COVER
ALTERNATE DESIGN OF ANGLE SHELF
STEEL WALL ½" THICK
GASKET
FILLER PLATE THICKNESS = ½" + THICKNESS OF GASKET
3½" x 1" x 20" STEEL SHELF
3½"
7½" x ¼" PLATE COVER
PREFERRED DESIGN OF PLATE SHELF AND COVER
NOT LESS THAN 50" MEASURED ON OUTSIDE OF DRUM
20"
CAST STEEL OR ROLLED STEEL ENDS NOT LESS THAN ½" THICK
SUGGESTED MOTOR NOT LESS THAN 1 H.P.
6" OPENING
28" d.
GASKET
DIRECTION OF ROTATION
SHAFT BEARING WILL BE MOUNTED ON CONCRETE PIERS OR OTHER RIGID SUPPORTS
CONCRETE PIER
CATCH PAN FOR SPECIMEN

FIG. 1.—Los Angeles Abrasion Testing Machine.

Combined carbon, min., per cent	2.50
Graphitic carbon, max., per cent	0.25
Silicon, max., per cent	1.00
Manganese, max., per cent	0.50
Phosphorus, max., per cent	0.25
Sulfur, max., per cent	0.08

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[1] These requirements are identical with those for the cast-iron spheres used in the rattler test for paving brick as prescribed in the Tentative Specifications for Paving Brick (A.S.T.M. Designation: C 7 – 38 T), see p. 771.

(*b*) A charge of 12 spheres weighing 5000 g. ± 25 g. shall be used with the grading *A* described in Section 4, and a charge of 11 spheres weighing 4583 g. ± 25 g. shall be used with the grading *B* described in Section 4.

NOTE.—The limiting weight for each cast-iron or steel sphere permits the use of a charge consisting of a mixture of steel balls $1\frac{7}{8}$ in. and $1\frac{13}{16}$ in. in diameter. When steel spheres heavier than the prescribed weights are obtained, it is suggested that they be reduced in size by grinding. Cast-iron spheres, uniform in size, meeting these specifications are readily available.

Test Sample

4. The test sample shall consist of 5000 g. of clean, dry aggregate and shall conform to either of the following gradings. The grading used shall be that most nearly representing the aggregate furnished for the work.

SIEVE SIZE (SQUARE OPENINGS)		GRADING *A*	GRADING *B*
PASSING	RETAINED ON	WEIGHT, G.	WEIGHT, G.
$1\frac{1}{2}$ in.	1 in.	1250	0
1 in.	$\frac{3}{4}$ in.	1250	0
$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	1250	2500
$\frac{1}{2}$ in.	$\frac{3}{8}$ in.	1250	2500

Procedure

5. The test sample and the abrasive charge shall be placed in the Los Angeles abrasion testing machine and the machine rotated for 500 revolutions at a speed of from 30 to 33 r.p.m. If an angle is used as the shelf, the machine shall be rotated in such a direction that the charge is caught on the outside surface of the angle. At the completion of the test, the material shall be removed from the machine and sieved on a No. 12 sieve conforming to the requirements of the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1] The material retained on the sieve shall be washed, dried, and accurately weighed to the nearest gram (Note).

NOTE.—Attention is called to the fact that valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 100 revolutions; when this determination is made care should be taken to avoid loss of any part of the sample; the entire sample, including the dust of abrasion, shall be returned to the testing machine for the completion of the test.

Calculation

6. The difference between the original weight and the final weight of the test sample shall be expressed as a percentage of the original weight of the test sample. This value shall be reported as the percentage of wear.

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[1] See p. 1289.

TENTATIVE METHOD OF TEST
FOR
CLAY LUMPS IN AGGREGATES[1]

A.S.T.M. Designation: C 142 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. This method of test is intended for the approximate determination of clay lumps in the routine examination of aggregates.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—Balance or scale sensitive to within 0.1 per cent of the weight of the sample to be tested.

(*b*) *Containers.*—Containers of a size and shape which will permit the spreading of the sample on the bottom in a thin layer.

(*c*) *Sieves.*—Sieves conforming to the requirements appearing in Table I of the Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates (A.S.T.M. Designation: C 136 – 38 T) of the American Society for Testing Materials.[3]

Samples

3. (*a*) Samples shall be obtained by quartering or by the use of a sampler from a representative sample selected from the material to be tested. They shall be handled in such a manner as to avoid breaking up clay lumps which may be present.

(*b*) Samples shall be dried to substantially constant weight at a temperature not exceeding 110 C. (230 F.).

(*c*) Fine-aggregate samples shall consist of the particles coarser than a No. 16 sieve and shall weigh not less than 100 g.

(*d*) Coarse-aggregate samples shall be separated into different sizes using the following sieves: No. 4, $\frac{3}{8}$-in., $\frac{3}{4}$-in., and $1\frac{1}{2}$-in. The weight of sample for the different sizes shall be not less than indicated in the following table:

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

[3] See p. 808.

SIZE OF PARTICLES MAKING UP SAMPLE	MINIMUM WEIGHT OF SAMPLE, G.
No. 4 to $\frac{3}{8}$-in.	1000
$\frac{3}{8}$ to $\frac{3}{4}$-in.	2000
$\frac{3}{4}$ to $1\frac{1}{2}$-in.	3000
Over $1\frac{1}{2}$-in.	5000

(*e*) In the case of mixtures of fine and coarse aggregate, the material shall be separated into two sizes on the No. 4 sieve and the samples of fine and coarse aggregate prepared in accordance with Paragraphs (*c*) and (*d*).

Procedure

4. The sample shall be spread in a thin layer on the bottom of the container and examined for clay lumps. Any particles which can be broken into finely divided particles with the fingers shall be classified as clay lumps. After all discernible clay lumps have been broken, the residue from the clay lumps shall be removed by use of the sieves indicated in the following table:

SIZE OF PARTICLES MAKING UP SAMPLE	SIZE OF SIEVE FOR SIEVING RESIDUE OF CLAY LUMPS
Fine aggregate (retained on No. 16 sieve)	No. 20
No. 4 to $\frac{3}{8}$-in.	No. 8
$\frac{3}{8}$ to $\frac{3}{4}$-in.	No. 4
$\frac{3}{4}$ to $1\frac{1}{2}$-in.	No. 4
Over $1\frac{1}{2}$-in.	No. 4

Calculation

5. The percentage of clay lumps shall be calculated to the nearest 0.1 per cent in accordance with the following formula:

$$\text{Percentage of clay lumps} = \frac{100 \times (\text{weight of sample}) - (\text{weight of sample after removal of clay lumps})}{\text{Weight of sample}}$$

TENTATIVE METHOD OF TEST
FOR
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES[1]

A.S.T.M. Designation: C 136 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method of test covers the determination of the particle size distribution of fine and coarse aggregates, using sieves with square openings. The method is also applicable to the use of laboratory screens with round openings. It is not intended for use in the sieve analysis of aggregates recovered from bituminous mixtures, or for the sieve analysis of mineral fillers.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—The balance or scale shall be sensitive to within 0.1 per cent of the weight of the sample to be tested.

(*b*) *Sieves.*—The sieves with square openings shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The woven wire cloth sieves shall conform to the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2]

NOTE.—If perforated plate sieves are used, the openings shall conform to the applicable dimensions and tolerances for round-hole screens prescribed in the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2]

Size of Sample

3. (*a*) Samples for sieve analysis shall be obtained, by quartering or by use of a sampler, from a representative sample selected from the material to be tested.

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[1] Under the standardization procedure of the Society, this method is under the joint jurisdiction of A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates and Committee D-4 on Road and Paving Materials.

This method is in effect a revision and consolidation of, and replaces the former Standard Methods of Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete (D 7 - 27), of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 18 - 16), of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 19 - 16), and Test for Sieve Analysis of Aggregates for Concrete (C 41 - 36), which standards were accordingly discontinued in 1938.

[2] See p. 1289.

(*b*) Fine aggregate samples for sieve analysis shall weigh, after drying, not less than the amount indicated in the following table:

Material with at least 95 per cent finer than a No. 10 sieve	100 g.
Material with at least 90 per cent finer than a No. 4 sieve and more than 5 per cent coarser than a No. 10 sieve	500 g.

(*c*) Coarse aggregate samples for sieve analysis shall weigh, after drying, not less than an amount indicated in the following table:

NOMINAL MAXIMUM SIZE OF PARTICLE, IN.	MINIMUM WEIGHT OF SAMPLE, G.[a]
⅜	1 000
½	2 500
¾	5 000
1	10 000
1½	15 000
2	20 000
2½	25 000
3	30 000
3½	35 000

[a] For samples weighing 5000 g. or more it is recommended that sieves mounted in frames 16 in. in diameter or larger be used.

(*d*) In the case of mixtures of fine and coarse aggregates, the material shall be separated into two sizes on the No. 4 sieve and the samples of fine and coarse aggregates prepared in accordance with Paragraphs (*b*) and (*c*).

(*e*) In the case of fine aggregate, the material finer than the No. 200 sieve shall be determined in accordance with the Standard Method of Test for Determination of Amount of Material Finer than No. 200 Sieve in Aggregates (A.S.T.M. Designation: C 117) of the American Society for Testing Materials[1] and the sieve analysis made on the material coarser than the No. 200 sieve.

Drying of Sample

4. Samples shall be dried to substantially constant weight at a temperature not exceeding 110 C. (230 F.).

Procedure

5. (*a*) The sample shall be separated into a series of sizes using such sieves as are necessary to determine compliance with the specifications for the material under test. The sieving operation shall be conducted by means of a lateral and vertical motion of the sieve, accompanied by jarring action so as to keep the sample moving continuously over the surface of the sieve. In no case shall fragments in the sample be turned or manipulated through the sieve by hand. Sieving shall be continued until not more than 1 per cent by weight of the residue passes any sieve during 1 min. On that portion of the sample retained on the No. 4 sieve, the above described procedure for determining thoroughness of sieving shall be carried out with a single layer

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 99.

of material. When sieving machines are used, their thoroughness of sieving shall be tested by using the hand method of sieving as described above.

(*b*) The weight of each size shall be determined on a scale or balance conforming to the requirements specified in Section 2 (*a*).

(*c*) The results of the sieve analysis shall be reported as follows: (*1*) total percentages passing each sieve, or (*2*) total percentages retained on each sieve, or (*3*) percentages retained between consecutive sieves, depending upon the form of the specifications for the use of the material under test. Percentages shall be reported to the nearest whole number and shall be calculated on the basis of the weight of the test sample including any material finer than the No. 200 sieve.

TENTATIVE METHOD OF TEST

FOR

SOUNDNESS OF AGGREGATES BY FREEZING AND THAWING[1]

A.S.T.M. Designation: C 137 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method describes the procedure to be followed in testing aggregates to determine their resistance to disintegration by freezing and thawing. It furnishes information helpful in judging the soundness of aggregates subjected to weathering action. However, in selecting aggregates, principal dependence should be placed on service records of the materials when exposed to actual weathering conditions. In the absence of such information, this test method affords a useful guide. Because of the limited amount of information concerning the significance of the test results and because of the lack of information as to the uniformity of tests made in different laboratories, the test method should not be used as an arbitrary basis of rejection; it should be used only to furnish information to indicate whether or not the materials require further investigation of their soundness.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Compressor.*—The compressor shall be of such type and capacity that it will be able to maintain the temperature hereinafter required.

(*b*) *Freezing Chamber*[2].—The freezing chamber shall be rectangular in cross-section, 12 by 20 in. by 24 in. deep, a tolerance of plus or minus 2 in. shall be permissible for each of these dimensions. The bottom and sides of the chamber shall be insulated with cork board not less than 6 in. in thickness (except where a side may be adjacent to another similar chamber) and fitted with a close-fitting lid of cork board not less than 4 in. in thickness. The chamber shall be provided with a suitable inlet and outlet to provide for the circulation of a non-freezing solution as provided for in this method.

(*c*) *Circulator.*—A circulator shall be provided of such capacity as may be required to maintain the temperatures hereinafter specified.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M Committee C-9 on Concrete and Concrete Aggregates.

[2] The number of freezing chambers may be varied with the scope of the program to be carried out.

(*d*) *Trays and Containers.*—The sample of aggregate shall be placed in shallow metal trays 3½ in. in width, 18 in. in length, and 2½ in. in depth (outside dimensions). These trays shall be nested in a metal container 3⅞ in. in width, 18¼ in. in length, and 20 in. in depth. The containers shall be placed in a freezing chamber and the space between the containers and the walls of the freezing chamber shall be occupied by a circulating non-freezing solution of alcohol and water.

(*e*) *Sieves.*—Sieves Nos. 100, 50, 30, 16, 8, and 4, conforming to the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials,[1] and sieves with square openings in sizes ⅜ in., ¾ in., 2½ in., 1½ in., and larger sizes by 1-in. spread for screening the samples in accordance with Sections 4 and 5.

(*f*) *Balances.*—For fine aggregate a balance having a capacity not less than 500 g., sensitive to at least 0.1 g., shall be used; for coarse aggregate a balance having a capacity not less than 5000 g., sensitive to at least 1 g. shall be used.

(*g*) *Drying Oven.*—The drying oven shall provide a free circulation of air through the oven and shall be capable of maintaining a temperature of 105 to 110 C. (221 to 230 F.).

(*h*) *Thawing Tank.*—A thawing tank shall be provided of such dimensions as to permit the complete submergence of the specimens in their trays. Adequate means shall be provided so that the water in the tank may be kept at a temperature between 75 and 80 F. (24 and 27 C.) during the thawing period.

Samples

3. (*a*) *Fine Aggregate.*—Fine aggregate for the test shall be passed through a ⅜-in. sieve. The sample shall be of such size that it will yield not less than 100 g. of each of the following sizes, which are available in amounts of 5 per cent or more, expressed in terms of the following A.S.T.M. sieves:

Retained on sieve No. 100, passing sieve No. 50
Retained on sieve No. 50, passing sieve No. 30
Retained on sieve No. 30, passing sieve No. 16
Retained on sieve No. 16, passing sieve No. 8
Retained on sieve No. 8, passing sieve No. 4
Retained on sieve No. 4, passing ⅜-in. sieve

(*b*) *Coarse Aggregate.*—Coarse aggregate for the test shall consist of material from which the sizes finer than the No. 4 sieve have been removed. The sample shall be of such a size that it will yield not less than the following amounts of the different sizes, which are available in amounts of 5 per cent or more:

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[1] See p. 1289.

No. 4 to ⅜-in. size (square openings)	100 g.
⅜ to ¾-in. size (square openings)	300 g.
¾ to 1½-in. size (square openings)	1500 g.
1½ to 2½-in. size (square openings)	3000 g.
Larger sizes by 1-in. spread in sieve size, each fraction	3000 g.

(*c*) Should the sample contain less than 5 per cent of any of the sizes specified in Paragraph (*a*) or (*b*), that size shall not be tested, but, for the purpose of calculating the test results, it shall be considered to have the same loss during the treatment as the average of the next smaller and the next larger size, or if one of these sizes is absent, it shall be considered to have the same loss as the next larger or next smaller size whichever is present.

Preparation of Test Sample

4. (*a*) *Fine Aggregate.*—The sample of fine aggregate shall be thoroughly washed on a No. 100 sieve and dried to constant weight at a temperature of 105 to 110 C. (221 to 230 F.) and separated into the different sizes by sieving, as follows: Make a rough separation of the graded sample by means of a nest of the standard sieves specified in Section 3 (*a*). From the fractions obtained in this manner select samples of sufficient size to yield 100 g. after sieving to refusal. (In general, a 110-g. sample will be sufficient.) Fine aggregate sticking in the meshes of the sieves shall not be used in preparing the samples. Samples consisting of 100 g. shall be weighed out of each of the separated fractions after final sieving and placed in separate containers for the test.

(*b*) *Coarse Aggregate.*—The sample of coarse aggregate shall be thoroughly washed and dried to constant weight at a temperature of 105 to 110 C. (221 to 230 F.) and shall be separated into the different sizes shown in Section 3 (*b*) by screening to refusal. The proper weight of sample for each fraction shall be weighed out and placed in separate containers for the test. In the case of fractions coarser than the ¾-in. sieve, the number of particles shall be counted.

(*c*) *Ledge Rock.*—For testing ledge rock, the sample shall be prepared by breaking it into fragments reasonably uniform in size and shape and weighing approximately 100 g. each. The test sample shall weigh 5000 g. ± 2 per cent. The sample shall be thoroughly washed and dried previous to test as described in Paragraph (*b*).

Method of Exposure[1]

5. (*a*) Samples of aggregate shall be placed in trays and immersed in the thawing tank 24 hr. before the start of the freezing-and-thawing test. The trays shall then be removed from the tank and any water in excess of the amount necessary for complete immersion of all aggregate particles shall

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[1] Variation in the temperature maintained in the freezing chamber, the rate of circulation, and the time in the chamber may be varied as a means of studying the effect of the rate of freezing upon the relative severity of the test.

be poured from the tray, and the trays nested in the containers previously mentioned. These containers shall then be placed in the freezing chamber and a nonfreezing solution shall circulate around the containers in such a manner that at no place shall there be a difference greater than 5 deg. Fahr. (2.8 deg. Cent.). Provision shall be made for rotation of the trays when starting the freezing cycle.

(*b*) The temperature of the nonfreezing solution as it enters shall be −20, ±2 F. (−29 ±1 C.) and as it leaves, shall be not more than −15, ±2 F. (−26 ±1 C.). The capacity of the refrigerator, and the rate of circulation shall be such that the above temperature conditions may be maintained in each freezing chamber.

(*c*) At the end of 2 hr. the trays shall be removed from the freezing chamber and immediately submerged in the thawing tank which shall be kept at a temperature between 75 and 80 F. (24 and 27 C.). The water in the thawing tank shall be kept in continuous motion so that the temperature difference in any part of the tank shall be within the above limits.

(*d*) At the end of 30 min. the trays may be removed from the thawing tank, drained as previously provided, and returned to the freezing chamber.

Cycles

6. The process of alternate freezing and thawing shall be repeated until the required number of cycles is obtained.

Measurement of Disintegration

7. The extent of disintegration produced by the test shall be determined by means of quantitative and qualitative methods.

Quantitative Examination

8. The quantitative examination (Note) shall be made as follows:

(*a*) After the completion of the final cycle, the sample shall be dried to constant weight at 105 to 110 C. (221 to 230 F.); weighed, and, except in the base of ledge rock, screened over the same sieve on which it was retained before the test. The particles retained on this sieve shall be weighed and the weight recorded.

NOTE.—In addition to the procedure described in Paragraph (*a*) it is suggested that additional information of value will be obtained by examining each fraction visually in order to determine if there is any evidence of excessive splitting of the grains. It is suggested also that additional information of value will be obtained if, after treating each separate fraction of the sample as described in Paragraph (*a*), all sizes, including detritus, shall be combined and a sieve analysis made using a complete set of sieves for the determination of the fineness modulus. The results of the sieve analysis shall be recorded as cumulative percentages retained on each sieve.

(*b*) In the case of ledge rock the loss in weight shall be determined by subtracting from the original weight of the sample the final weight of all original fragments which have not broken into three or more pieces.

Qualitative Examination

9. (*a*) Fractions of samples coarser than ¾ in. shall be examined qualitatively after each 10 cycles and quantitatively at the completion of the test.

(*b*) The qualitative examination and record shall consist of two parts: (1) Observing the effect of the action (Note) and the nature of the action, and (2) counting the number of particles affected.

NOTE.—Many types of action may be expected. In general, they may be classified as disintegration, splitting, crumbling, cracking, flaking, etc.

While only particles larger than the ¾ in. in size are required to be examined qualitatively, it is recommended that examination of the smaller sizes be made in order to determine if there is any evidence of excessive splitting.

Report

10. The report shall include the following data (Note):

NOTE.—The following table is a suggested form for recording test data.

Sieve Size		Grading of Original Sample, per cent	Weight of Test Fractions Before Test, g.	Percentage Passing Finer Sieve After Test (Actual per cent Loss)	Weighted Average (Corrected per cent Loss)
Passing	Retained on				
SOUNDNESS TEST OF FINE AGGREGATE					
No. 100					
No. 50	No. 100				
No. 30	No. 50				
No. 16	No. 30				
No. 8	No. 16				
No. 4	No. 8				
⅜ in.	No. 4				
Totals					
SOUNDNESS TEST OF COARSE AGGREGATE					
2½ in.	1½ in.				
1½ in.	¾ in.				
¾ in.	⅜ in.				
⅜ in.	No. 4				
Totals					

(*a*) Weight of each fraction of each sample before test.

(*b*) Except in the case of ledge rock, material from each fraction of the sample, finer than sieve on which fraction was retained before test, expressed as a percentage by weight of the fraction.

(*c*) Weighted average calculated from the percentage of loss for each fraction, based on the grading of the sample as received for examination, or preferably, on the average grading of the material from that portion of the supply of which the sample is representative.

(*d*) In the case of particles coarser than ¾ in. before test:
  (*1*) Number of particles in each fraction before test, and
  (*2*) Number of particles affected, classified as to number disintegrating, splitting, crumbling, cracking, flaking, etc.

(*e*) In the case of ledge rock:
  (*1*) The percentage of loss calculated as described in Section 8 (*b*), and
  (*2*) The number of pieces affected, classified as to number disintegrating, splitting, crumbling, cracking, flaking, etc.

TENTATIVE METHOD OF TEST
FOR
UNIT WEIGHT OF AGGREGATE[1]

A.S.T.M. Designation: C 29 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. This method is intended for use in determining the unit weight of fine, coarse, or mixed aggregate.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance or scale sensitive to 0.5 per cent of the weight of the sample to be weighed.

(*b*) *Tamping Rod.*—A straight metal rod, $\frac{5}{8}$ in. in diameter and 24 in. in length, with one end tapered for a distance of 1 in. to a blunt bullet-shaped point.

(*c*) *Measure.*—A metal measure, cylindrical in form, and preferably provided with handles. It shall be watertight, with the top and bottom true and even, preferably machined to accurate dimensions on the inside, and of sufficient rigidity to retain its form under rough usage. The $\frac{1}{2}$ and 1-cu.-ft. measures shall be reinforced around the top with a No. 11 gage steel band $1\frac{1}{2}$ in. in width. The measures required, depending upon the maximum size of the coarsest particles in the aggregate to be tested, shall have capacities of $\frac{1}{10}$, $\frac{1}{2}$, or 1 cu. ft. and shall conform to the following dimensional requirements:

Capacity, cu. ft.	Inside Diameter, in.	Inside Height, in.	Minimum Thickness of Metal, U. S. Gage	Size of Largest Particles of Aggregate, in.
$\frac{1}{10}$	6.00	6.10	No. 11	$\frac{1}{2}$
$\frac{1}{2}$	10.00	11.00	No. 11	$1\frac{1}{2}$
1	14.00	11.23	No. 11	4

Calibration of Measure

3. The measure shall be calibrated by accurately determining the weight of water at 16.7 C. (62 F.) required to fill it. The factor for any

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

This method is in effect a tentative revision of and will supersede when adopted as standard the present Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27) 1936 Book of A.S.T.M. Standards, Part II, p. 364.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

unit shall be obtained by dividing the unit weight of water at 16.7 C. (62 F.) (62.355 lb. per cu. ft.) by the weight of water at 16.7 C. (62 F.) required to fill the measure.

Sample

4. The sample of aggregate shall be room dry and thoroughly mixed.

Rodding Method

5. The rodding method is applicable to aggregates having a maximum size of 2 in. or less.

(*a*) The measure shall be filled one-third full and the top leveled-off with the fingers. The mass shall be rodded with the tamping rod with 25 strokes, evenly distributed over the surface. The measure shall be filled two-thirds full and again rodded with 25 strokes as before. The measure shall then be filled to overflowing, rodded 25 times, and the surplus aggregate struck-off, using the tamping rod as a straight edge.

(*b*) In rodding the first layer, the rod shall not be permitted to forcibly strike the bottom of the measure. In rodding the second and final layers, only enough force shall be used to cause the tamping rod to penetrate the last layer of aggregate placed in the measure.

(*c*) The net weight of the aggregate in the measure shall be determined. The unit weight of the aggregate shall then be obtained by multiplying the net weight of the aggregate by the factor found as described in Section 3.

Jigging Method

6. The jigging method is applicable to aggregates having a maximum size greater than 2 in.

(*a*) The measure shall be filled in three approximately equal layers as described in Section 5 (*a*), each layer being compacted by placing the measure on a firm foundation, such as a cement-concrete floor, and raising alternate sides of the measure about 2 in. from the foundation and allowing it to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a closely compacted condition. Each layer shall be compacted by dropping the measure 50 times in the manner described, 25 times on each side. The surface of the aggregate shall then be leveled-off with the fingers, or a straight edge, in such a way that any slight projections of the larger pieces of the coarse aggregate shall balance the larger voids in the surface below the top of the measure.

(*b*) The net weight of the aggregate in the measure shall be determined. The unit weight of the aggregate shall then be obtained by multiplying the net weight of the aggregate by the factor found as described in Section 3.

Reproducibility of Results

7. Results with the same sample should check within 1 per cent.

TENTATIVE METHOD OF TEST
FOR
YIELD OF CONCRETE[1]

A.S.T.M. Designation: C 138 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method is intended to cover a test procedure for the determination of the volume of freshly mixed concrete produced from a mixture of known quantities of the component ingredients, from which may be calculated the "yield," that is, the volume of concrete per unit volume of cement. Unless otherwise stated, "yield" will be expressed in terms of cubic feet of concrete per 94-lb. sack of cement.

Weight per Cubic Foot of Concrete

2. A representative sample of the concrete shall be placed in three layers of approximately equal thickness in the appropriate standard measure. The size of the standard measure shall be as specified in the Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29) of the American Society for Testing Materials.[2,3] The measure shall have been calibrated prior to use. Plastic concrete shall be compacted by rodding each layer separately as provided in the Standard Method C 29. Concrete designed for vibration shall be compacted by vibration to the proper density. After consolidation of the concrete, the measure shall be struck-off smoothly with a straight edge or flat surface, using great care to have the measure just level full.[4] All excess concrete shall be cleaned from the filled measure and it shall be immediately weighed to the nearest 0.1 lb. The net weight of the concrete in pounds per cubic foot shall be determined by subtracting the weight of the measure from the gross weight and applying the calibration factor.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 364.

[3] A tentative revision of this method appears on page 817.

[4] This method may be accomplished advantageously by the use of a flat cover plate.

Calculations for "Yield"

3. The "yield" of concrete shall be calculated in accordance with the following formulas:

$$S = \frac{N \times 94 + W_f + W_c + W_w}{W}$$

$$\text{Yield} = \frac{S}{N} = \text{cubic feet of concrete produced per 94 lb. sack of cement}$$

$$\text{Number of sacks of cement per cubic yard of concrete} = \frac{27}{\text{yield}} = \frac{27N}{S}$$

where S = the cubic feet of concrete produced,
W = the weight per cubic foot of the concrete sample,
N = the number of sacks of cement in the batch,
94 = the weight in pounds of a sack of cement,
W_f = the total weight in batch of fine aggregate in condition used,
W_c = the total weight in batch of coarse aggregate in condition used, and
W_w = the weight of mixing water added.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM POWDER FOR PAINTS[1]
(ALUMINUM BRONZE POWDER)

A.S.T.M. Designation: D 266 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover aluminum powder for use in paints, commonly known as aluminum bronze powder. Two types are provided as follows:

Type A.—Standard fineness, for general paint use.

Type B.—Extra fine, for special uses.

Composition and Properties

2. (*a*) The aluminum powder shall consist of commercially pure aluminum, in the form of fine, polished flakes and shall contain no filler or adulterant, such as mica. The powder shall be suitable for making aluminum paint and shall also conform to the following requirements:

Coarse particles, max., per cent	Type A, total residue retained on a No. 100 sieve	0.2
	Type B, total residue retained on a No. 325 sieve	1.0
Easily extracted fatty and oily matter (polishing lubricant), max., per cent		3.0
Total impurities, other than fatty and oily matter, max., per cent		2.0

(*b*) The powder shall show good "leafing" quality. A paint made from the powder shall be free flowing and shall give a continuous coating at least equal in smoothness, luster and general appearance, to that of a sample mutually agreed upon by the purchaser and the seller.

Number of Tests

3. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof, for purpose of tests.

Methods of Test

4. Several of the methods for testing aluminum powder are empirical and the results are affected by the method. The operator shall follow closely the procedures described in the Tentative Methods of Sampling and Testing Aluminum Powder and Aluminum Paste (A.S.T.M. Designation: D 480 - 38 T) of the American Society for Testing Materials.[2]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

These tentative specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 - 31), 1936 Book of A.S.T.M. Standards, Part II, p. 565.

[2] See p. 835.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM PIGMENT PASTE FOR PAINT[1]

A.S.T.M. Designation: D 474 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover aluminum pigment paste for use in paints. Two types are provided, as follows:

Type A.—Standard fineness, for general paint use.

Type B.—Extra fine "lining," for special finishes.

Composition and Properties

2. (*a*) The aluminum pigment paste shall consist of commercially pure aluminum in the form of fine, polished flakes, combined with a volatile paint thinner and a suitable fatty lubricant, to form a paste suitable for use as a paint pigment. It shall contain no fillers or adulterants, such as mica.

The paste shall conform to the following requirements:

Nonvolatile matter at 105 to 110 C., min., per cent		64.5
Coarse particles, total residue retained on a No. 325 sieve, max., per cent	Type A	1.5
	Type B	0.1
Easily extracted fatty and oily matter (polishing lubricant), max., per cent		4.0
Total impurities, other than fatty and oily matter, max., per cent		1.0

NOTE.—All of the above limits are expressed in percentage of the *paste.*

(*b*) The paste shall show good "leafing" quality. A paint made with the paste shall be free flowing and shall give a continuous coating at least equal in smoothness, luster and general appearance, to that of a sample mutually agreed upon by the purchaser and the seller.

(*c*) Paste of both types shall meet the stability test described in Section 4. Paste which, within six months' storage in unopened original packages, after shipment, is found to be unfit for use, will be rejected.

Number of Tests

3. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof, for purpose of tests.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

Methods of Test

4. Several of the methods for testing aluminum paste are empirical, and the results are affected by the method. The operator shall follow closely the procedures described in the Tentative Methods of Sampling and Testing Aluminum Powder and Aluminum Paste (A.S.T.M. Designation: D 480 - 38 T) of the American Society for Testing Materials.[1]

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[1] See p. 835.

TENTATIVE SPECIFICATIONS
FOR
REDUCED PARA RED[1]

A.S.T.M. Designation: D 264 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover a red pigment commonly known as reduced para red. The pigment may be purchased in the dry form or dispersed in oil or in japan to form a paste.

Composition

2. (*a*) *Dry Pigment.*—The pigment shall consist of a mixture of paranitraniline toner and substrate, made either by precipitating the toner on the substrate, or by mixing slurries. Unless otherwise specified by the purchaser, the substrate shall be calcium carbonate.

(*b*) *Paste in Oil.*—The paste in oil shall be a dispersion of the specified pigment in linseed oil.

(*c*) *Paste in Japan.*—The paste in japan shall be a dispersion of the specified pigment in high-grade grinding japan.

Properties

3. (*a*) The mass color and character of the tint formed by mixture with a white pigment shall be the same as, and the strength shall be not less than that of a sample mutually agreed upon by the purchaser and the seller.

(*b*) *Dry Pigment.*—The dry pigment shall conform to the following requirements:

Pure organic coloring matter (para red), min., per cent	15.0
Calcium carbonate, max., per cent	85.0
Coarse particles, total residue retained on a No. 325 sieve, max., per cent	1.5

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions, without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any mixture of these substances.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

These tentative specifications are in effect a tentative revision of, and will supersede when adopted as standard, the present Standard Specifications for Commercial Para Red (D 264 – 28), 1936 Book of A.S.T.M. Standards, Part II, p. 586.

The paste shall conform to the following requirements:

Pigment, min., per cent	74.0
Linseed oil, max., per cent	26.0
Moisture and other volatile matter, max., per cent	0.7
Coarse particles and skins, total residue retained on a No. 325 sieve, max., per cent of the dry pigment	2.0

(*d*) *Paste in Japan.*—The paste as received shall not be caked in the container and shall break up readily in turpentine to form a smooth paint of brushing consistency that will dry within 1 hr. to a hard flat coat that can be varnished within 5 hr. after the time of application.

The paste shall conform to the following requirements:

Pigment, min., per cent	74.0
Vehicle (japan), per cent	26.0
Coarse particles and skins, total residue retained on a No. 325 sieve, max., per cent of the dry pigment	2.0
Nonvolatile matter in the vehicle, min., per cent of the vehicle	40.0

Number of Tests

4. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof.

TENTATIVE SPECIFICATIONS

FOR

C.P. PARA RED TONER[1]

A.S.T.M. Designation: D 475 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

1. These specifications cover a red pigment commonly known as "chemically pure" para red toner. The pigment may be purchased in dry form or dispersed in oil to form a paste.

Composition

2. (*a*) *Dry Pigment.*—The pigment shall consist of pure para-nitraniline red toner free from any substrate.

(*b*) *Paste in Oil.*—The paste in oil shall be a dispersion of the specified pigment in linseed oil.

Properties

3. (*a*) The mass color and character of the tint formed by mixture with a white pigment shall be the same as, and the strength shall be not less than that of a sample mutually agreed upon by the purchaser and the seller.

(*b*) *Dry Pigment.*—The dry pigment shall conform to the following requirements:

Pure organic coloring matter, min., per cent	97.0
Ash, max., per cent	3.0
Coarse particles, total residue retained on a No. 325 sieve, max., per cent	1.5

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions, without curdling, with linseed oil, turpentine, or volatile mineral spirits, or any mixture of these substances.

The paste shall conform to the following requirements:

Pigment, min., per cent	40.0
Linseed oil, max., per cent	60.0
Moisture and other volatile matter, max., per cent	0.7
Coarse particles and skins, total residue retained on a No. 325 sieve, max., per cent of the dry pigment	2.0

Number of Tests

4. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

TENTATIVE SPECIFICATIONS

FOR

RED LEAD[1]

A.S.T.M. Designation: D 83 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover three grades of red pigment commonly known as red lead. The pigment may be purchased in the dry form or as a paste in oil.

Composition

2. (*a*) *Dry Pigment.*—The pigment shall be made by roasting litharge or metallic lead, or compounds of lead which yield litharge by heating.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with linseed oil.

NOTE.—Purchasers are cautioned that 85 per cent Grade red lead should not be bought in paste form. The 95 per cent Grade, if made into paste, should be used within a short period of time after grinding. When pure red lead paste is to be stored for a considerable period of time, the 97 per cent Grade of red lead should be specified.

The storage of paste red lead in places of high temperature should be avoided, as heat accelerates the tendency of this material to cake or harden.

Properties

3. (*a*) *Dry Pigment.*—The pigment shall consist entirely of oxides of lead, free from adulterants. Three grades of pigment are provided, which shall conform to the following requirements:

	85 PER CENT GRADE	95 PER CENT GRADE	97 PER CENT GRADE
True red lead (Pb_3O_4), min., per cent	85.0	95.0	97.0
Total impurities including moisture, soluble matter, and matter insoluble in a mixture of nitric acid and hydrogen peroxide, max., per cent	1.0	1.0	1.0
Lead monoxide, PbO	remainder	remainder	remainder
Coarse particles, total residue retained on a No. 325 sieve, max., per cent	1.0	1.0	1.0

When mixed as indicated in the following table, the resulting paint, brushed on a smooth vertical iron surface, shall dry hard and elastic without running, streaking, or sagging:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

These tentative specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Red Lead (D 83 - 31), 1936 Book of A.S.T.M. Standards, Part II, p. 590.

Dry red lead	20 lb.
Raw linseed oil	5 pt.
Turpentine	2 gills
Liquid drier	2 gills

(*b*) *Paste.*—The paste as shipped by the seller, and for three months thereafter, shall not be caked in the container, and shall break up readily in oil, to form a smooth paint of brushing consistency.

The paste shall conform to the following requirements:

Pigment, per cent	92.0 to 94.0
Linseed oil, per cent	6.0 to 8.0
Moisture and other volatile matter, max., per cent	0.5
Coarse particles and skins, total residue retained on a No. 325 sieve, max., per cent of the dry pigment	1.5

When mixed as indicated in the following table, the resulting paint, brushed on a smooth, vertical iron surface, shall dry hard and elastic without running, streaking, or sagging:

Red lead paste	20 lb.
Raw linseed oil	3 pt.
Turpentine	2 gills
Liquid drier	2 gills

Number of Tests

4. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

TENTATIVE SPECIFICATIONS
FOR
TITANIUM DIOXIDE PIGMENTS[1]

A.S.T.M. Designation: D 476 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover titanium dioxide pigments.

Composition

2. The respective pigments shall have the following compositions:

Titanium dioxide, commercially pure.

Titanium-Barium Pigment, a pigment consisting of titanium dioxide and barium sulfate.

Titanium-Calcium Pigment, a pigment consisting of titanium dioxide and anhydrous calcium sulfate.

Titanium-Magnesium Pigment, a pigment consisting of titanium dioxide and magnesium silicates with or without added micaceous silicates.

Properties

3. (*a*) In such physical properties as are specified by the purchaser, the pigment shall satisfactorily match a reference sample mutually agreed upon by the purchaser and the seller.

(*b*) The pigments of the respective classes shall also conform to the following requirements for composition:

	TITANIUM DIOXIDE PIGMENT	TITANIUM BARIUM PIGMENT	TITANIUM CALCIUM PIGMENT	TITANIUM MAGNESIUM PIGMENT
Coarse particles, total residue retained on a No. 325 sieve, max., per cent..	1.0	1.0	1.0	2.0
Titanium dioxide, min., per cent.....	97.0	24.0	28.0	28.0
Moisture and other matter volatile at 105 C., max., per cent..........	0.5	0.5	0.5	1.0
Barium sulfate, min................	....	98 per cent of remainder	....	....
Anhydrous calcium sulfate, min......	....	....	98 per cent of remainder	....
Magnesium and aluminum silicates, min..........................	....	....	....	98 per cent of remainder
Alumina, max., per cent............	....	....	....	7.5
Matter soluble in water, max., per cent	1.5	1.5	....	....

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

These specifications are in effect a revision and consolidation of, and are intended to replace when adopted as standard the Standard Specifications for Titanium Barium Pigment (D 382 – 35), Titanium Calcium Pigment (D 383 – 35), Titanium Dioxide (D 384 – 36), and the Tentative Specifications for Titanium Magnesium Pigment (D 442 – 37 T).

Number of Tests

4. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken from each carload.

Methods of Test

5. All tests shall be conducted in accordance with the current methods of the American Society for Testing Materials. The reference sample and any testing methods not standardized by the American Society for Testing Materials, shall be mutually agreed upon by the purchaser and the seller.

TENTATIVE SPECIFICATIONS
FOR
C.P. ZINC YELLOW (ZINC CHROMATE)[1]

A.S.T.M. Designation: D 478 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the yellow pigment commonly known as "chemically pure" zinc yellow or zinc chromate. The pigment may be purchased in the dry form or as a paste in oil.

Composition

2. (*a*) *Dry Pigment.*—The pigment shall consist of a complex salt of zinc and potassium chromates.

(*b*) *Paste in Oil.*—The paste in oil shall be a dispersion of the specified pigment in linseed oil.

Properties

3. (*a*) The mass color and character of the tint formed by mixture with a white pigment shall be the same as, and the strength shall not be less than, that of a sample mutually agreed upon by the purchaser and the seller.

(*b*) *Dry Pigment.*—The pigment shall be free from any lead compound, any organic coloring matter, or any substrate of any kind, and shall be completely soluble in acetic acid (10 per cent) at a temperature of 80 C.

The dry pigment shall conform to the following requirements:

Zinc oxide, ZnO, max., per cent	40.0
Chromic anhydride, CrO_3, min., per cent	41.0
Alkaline salts, calculated as K_2O, per cent	9.0 to 13.0
Combined water, max., per cent	8.0
Coarse particles, total residue retained on a No. 325 sieve, max., per cent	1.0

(*c*) *Paste in Oil.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions, without curdling, with linseed oil, turpentine or volatile petroleum spirits, or any mixture of these substances.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

The paste shall conform to the following requirements:

Pigment, min., per cent	74.0
Linseed oil, max., per cent	26.0
Moisture and other volatile matter, max., per cent	0.7
Coarse particles and skins, total residue retained on a No. 325 sieve, max., per cent of the dry pigment	1.5

Number of Tests

4. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof.

TENTATIVE SPECIFICATIONS
FOR
ZINC SULFIDE PIGMENTS[1]

A.S.T.M. Designation: D 477 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover zinc sulfide pigments.

Composition

2. The respective pigments shall have the following compositions:

Zinc Sulfide, commercially pure.

Lithopone, a pigment consisting of zinc sulfide and barium sulfate in approximately molecular ratio.

Zinc Sulfide-Barium Pigment, a pigment consisting of zinc sulfide and barium sulfate as indicated below.

Zinc Sulfide-Magnesium Pigment, a pigment consisting of zinc sulfide and magnesium silicates with or without added micaceous silicates.

Properties

3. (*a*) In such physical properties as are specified by the purchaser, the pigment shall satisfactorily match a reference sample mutually agreed upon by the purchaser and the seller.

(*b*) The pigments of the respective classes shall also conform to the following requirements for composition:

	ZINC SULFIDE	LITHOPONE	ZINC SULFIDE BARIUM PIGMENT	ZINC SULFIDE MAGNESIUM PIGMENT
Coarse particles:				
Total residue retained on a No. 100 sieve, max., per cent	....	....	....	0.1
Total residue retained on a No. 325 sieve, max., per cent	1.0	1.0	1.0	3.0
Zinc sulfide, min., per cent	97.0	26.0	45.0	45.0
Zinc oxide, max., per cent	1.0	1.0	1.0	1.0
Matter soluble in water, max., per cent	1.5	0.8	0.8	1.0
Moisture and other matter volatile at 105 C., max., per cent	0.5	0.5	0.5	1.0
Magnesium and micaceous silicates, min	....	....	....	98 per cent of remainder
Alumina, max., per cent	....	....	....	5.5
Barium sulfate, min	....	98 per cent of remainder	98 per cent of remainder	....

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

These specifications are in effect a revision and consolidation of, and are intended to replace when adopted as standard the Standard Specifications for Lithopone (D 208 - 26), Zinc Sulfide-Barium Pigment (D 385 - 36), Zinc Sulfide (D 386 - 36), and the Tentative Specifications for Zinc Sulfide Magnesium Pigment (D 443 - 37 T).

Number of Tests

4. One sample shall be taken at random from each lot of 1000 packages, or fraction thereof. If the packages are of such size that 1000 packages amount to more than one carload, one sample shall be taken from each carload.

Methods of Test

5. All tests shall be conducted in accordance with the current methods of the American Society for Testing Materials. The reference sample and any testing methods not standardized by the American Society for Testing Materials, shall be mutually agreed upon by the purchaser and the seller.

TENTATIVE METHODS
OF
SAMPLING AND TESTING ALUMINUM POWDER AND ALUMINUM PASTE[1]

A.S.T.M. Designation: D 480 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These methods cover the procedure for the sampling, qualitative analysis, and physical testing of aluminum powder and aluminum paste for paint.

Sampling

2. (*a*) Subject to mutual agreement between the seller and the purchaser, one package shall be taken as a representative sample, from each lot of 1000 packages, or fraction thereof. Whenever possible the original unopened package of the material to be tested shall be sent to the laboratory. If it is not possible to send the original package, the inspector representing the purchaser shall thoroughly mix the contents of the container and take a sample of not less than 0.5 lb. (0.227 kg.). This sample shall be placed in a clean, dry, metal or glass container which shall be nearly filled, then closed with a tight cover, sealed, marked, and sent to the laboratory for test.

(*b*) When requested, a duplicate sample may be taken from the same package and delivered to the seller, and the inspector may take a third sample to hold for test in case of disagreement.

Qualitative Analysis

3. (*a*) *Aluminum Powder.*—Wash approximately 0.5 g. of the aluminum powder with ether to remove most of the fatty or oily matter. Place the powder in a beaker and add 50 ml. of diluted HCl (1:1). If an appreciable amount of insoluble matter remains after the addition of the acid the powder does not meet the specifications. Dilute a portion of the HCl solution and saturate with H_2S. No appreciable precititate should form with pure aluminum powder. To another portion of the HCl solution add a slight excess of NH_4OH (sp. gr. 0.90) and note the characteristic precipitate of $Al(OH)_3$ (Note).

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer and Related Products.

(*b*) *Aluminum Paste.*—Volatilize the solvent from an approximately 0.5-g. sample of the aluminum paste, wash the residue with ether to remove most of the fatty and oily matter. Treat the sample in accordance with the procedure described in Paragraph (*a*).

NOTE.—In general these qualitative tests will suffice, but if doubt exists as to the purity of the powder or paste, a complete qualitative analysis shall be made. If the qualitative analysis indicates impurities in excess of the amount permitted, the total impurities shall be determined in accordance with the Tentative Method of Chemical Analysis of Aluminum and Light Aluminum Alloys (A.S.T.M. Designation: B 40 - 36 T) of the American Society for Testing Materials.[1]

Leafing Properties

4. *Aluminum Powder.*—Stir vigorously, for at least 2 min., a mixture of the sample with a suitable vehicle (Note 2) in the ratio of 10 g. of Type *A* powder, or 5 g. of Type *B* powder to 40 ml. of the vehicle. The container shall be of such diameter that the free surface of the liquid will have an area within the limits of 25 to 50 sq. cm. Two minutes after cessation of the stirring, the entire free surface of the mixture shall have the appearance of a continuous, brilliant film, indicating satisfactory leafing properties.

NOTE 1.—The leafing test specified for aluminum powder is not satisfactory for aluminum paste, and another method is under development.

NOTE 2.—A varnish conforming to the Federal Specifications for Mixing Varnish for Aluminum Paint (TT-V-81) is suitable for this purpose. The small spatula used for stirring should be withdrawn, touching it once against the side of the container. The time should be noted and the container allowed to remain undisturbed and free of air currents for the 2-min. period.

Brushing, Smoothness, Luster, and General Appearance

5. (*a*) *Aluminum Powder.*—Compare a sample of aluminum powder to be tested with a sample mutually agreed upon by the purchaser and the seller. Prepare separate mixtures of each of the samples using the same vehicle in accordance with the procedure described in the test for leafing properties in Section 4. Allow the mixture to stand for 2 hr. after the first stirring. Then stir each thoroughly again and apply by brushing to a clean, smooth glass or metal surface and also to white index cards of good quality. Allow the coatings to dry in a nearly vertical position, and by visual inspection compare the smoothness, luster, and general appearance of each coating.

(*b*) *Aluminum Paste.*—Compare a sample of aluminum paste to be tested with a sample mutually agreed upon by the purchaser and the seller. Prepare separate mixtures of each of the samples using the same vehicle in accordance with the procedure described in the test for leafing properties in Section 4. Allow the mixtures to stand for 10 min. after the first stirring. Then stir each thoroughly again and apply by brushing to a clean, smooth glass or metal surface and also to white index cards of good quality. Allow the coatings to dry in a nearly vertical position, and by visual inspection, compare the smoothness, luster and general appearance of each coating.

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[1] A.S.T.M. Methods of Chemical Analyses of Metals, p. 95 (1936).

Coarse Particles

6. (*a*) *Aluminum Powder.*—For Type *A* powder, use a No. 100 standard sieve[1] 3 in. in diameter and for Type *B* powder use a No. 325 standard sieve[1] 3 in. in diameter. Dry the sieve in an oven at a temperature of 105 to 110 C., cool and weigh accurately. Weight 5 g. of the powder, transfer to a beaker, add 100 ml. of mineral spirits, thoroughly mix to a uniform consistency and transfer to the sieve. The mineral spirits used for this test shall conform to the Tentative Specifications for Petroleum Spirits (Mineral Spirits) (A.S.T.M. Designation: D 235 – 34 T) of the American Society for Testing Materials.[2] Wash the sieve with mineral spirits until no more material passes through it (Note). Then wash with acetone, dry the sieve at a temperature of 105 to 110 C. for 1 hr., cool, and weigh. Calculate the percentage of coarse particles from the increase in weight of the sieve and the original weight of the sample.

NOTE.—A camel's hair brush or other aid shall not be used to turn or manipulate the material through the sieve.

(*b*) *Aluminum Paste.*—Determine the percentage of coarse particles in aluminum paste in accordance with the procedure described in Paragraph (*a*) using a No. 325 sieve for all types of paste.

Easily Extracted Fatty and Oily Matter

7. (*a*) *Aluminum Powder.*—Weigh accurately approximately 2 g. of the sample, transfer to a 200-ml. volumetric flask and add about 50 ml. of redistilled acetone. The acetone used for this test shall conform to the Standard Specifications for Acetone (A.S.T.M. Designation: D 329) of the American Society for Testing Materials.[3] Heat the mixture to boiling, agitating occasionally, cool, fill to the mark with acetone and mix. Allow the mixture to settle, draw off about half of the supernatant liquid and filter through dry paper. Discard the first 10 ml. of the filtrate, transfer 100 ml. of the clear filtrate to a weighed dish, evaporate the acetone at a temperature not above 75 C., heat the dish for 15 min. in an oven at 105 to 110 C., cool, weigh, and calculate the percentage of fatty and oily matter.

NOTE.—This is an arbitrary method and the details of the test procedure shall be strictly followed.

(*b*) *Aluminum Paste.*—Determine the percentage of easily extracted fatty and oily matter in aluminum paste in accordance with the procedure described in Paragraph (*a*).

Stability

8. *Aluminum Paste.*—Add 1 ml. of water to a $\frac{1}{4}$-pt. tin-plated container approximately $2\frac{1}{2}$ in. in diameter and 2 in. in height, provided with a double-

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[1] For detailed specifications for these sieves, see the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, p. 1289.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 876 (1934); also 1938 Book of A.S.T.M. Tentative Standards, p. 740.

[3] 1936 Book of A.S.T.M. Standards, Part II, p. 784.

friction type seat cover (Note 1). Place the cover loosely on the container and heat in a low-temperature oven until the water is vaporized, remove from the oven, and cool so that the water will condense on the surface of the can. Weigh 100 g. of the paste and place in the container, with a minimum disturbance of the droplets of water. By means of a spatula, break up the paste so as to provide maximum exposure to the moisture. Place the cover on the can and seal tightly. Heat in a thermostatically-controlled oven at 45 ± 0.5 C. for a period of 24 hr. Mix the paste which has been heated in the presence of moisture, with varnish in the proportions of 10 g. of Type *A* paste, or 6 g. of Type *B* paste, with 40 ml. of varnish (Note 2). The resulting paint, when brushed on metal or glass panels and allowed to dry in a vertical position, shall present the brilliant, lustrous surface which is characteristic of an acceptable aluminum paint. The finish shall be practically equivalent to the finish obtained from a mixture prepared with a sample of the same paste without the addition of water and heating.

NOTE 1.—It is important that the size of the container used shall be as specified.

NOTE 2.—A varnish conforming to the Federal Specifications for Mixing Varnish for Aluminum Paint (TT–V–81) is suitable for this purpose.

Nonvolatile Matter

9. *Aluminum Paste.*—Weigh 5 g. of the paste into a tared evaporating dish. Heat in an oven at a temperature of 105 to 110 C. for 3 hr., cool, and weigh. Calculate the percentage of nonvolatile matter in the sample from the loss in weight, as follows:

$$\text{Nonvolatile matter, per cent} = \frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100$$

TENTATIVE METHODS OF ROUTINE ANALYSIS
OF
ZINC YELLOW PIGMENT (ZINC CHROMATE YELLOW)[1]

A.S.T.M. Designation: D 444 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1937; Revised, 1938.

Scope

1. These methods cover the procedures for physical tests and chemical analysis of the pigment commonly known as "zinc yellow," or "zinc chromate yellow" (Notes 1, 2 and 3).

Treatment of Sample

2. Dry pigments, if lumpy or not finely ground, shall be ground to a fine powder for analysis. Large samples may be thoroughly mixed and a representative portion taken and powdered, if lumpy or not finely ground. The sample in all cases shall be thoroughly mixed before taking portions for analysis. Extracted pigments shall be ground to a fine powder, passed through a No. 80 sieve to remove any skins, and thoroughly mixed. The weighed portions of extracted pigments should be moistened with a little alcohol before adding reagents for analysis. All samples shall be preserved in stoppered bottles or containers.

METHODS OF PHYSICAL TESTING

Specific Gravity

3. True specific gravity shall be determined in accordance with the Standard Methods of Test for Specific Gravity of Pigments (A.S.T.M. Designation: D 153) of the American Society for Testing Materials.[2]

Tinting Strength

4. Tinting strength shall be determined in accordance with the Standard Methods of Test for Mass Color and Tinting Strength of Dry Color Pigments or Pastes (A.S.T.M. Designation: D 387) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 638.

[3] *Ibid.*, p. 651.

Moisture

5. Weigh 6 g. of zinc yellow in a tared moisture dish. Dry the specimen over night at 110 C. Cool, and weigh the specimen and calculate the percentage of moisture as follows:

$$\text{Moisture, per cent} = \frac{\text{Loss of weight} \times 100}{\text{Weight of sample}}$$

Combined Water and Moisture

6. Weigh 3 g. of the pigment and transfer to a porcelain boat. Introduce the boat with the charge into a silica combustion tube of an electrically-heated combustion furnace (of the type used for the determination of carbon in steel by direct combustion).[1] Place the boat at the center of the combustion tube maintained at a temperature of 1000 C. A current of pure dry air drawn through the tube sweeps the evolved moisture through a train of absorption tubes containing sulfuric acid or dry calcium chloride. The weight increase of the absorption tube represents the "combined water" (including moisture). Report the results as combined water.

NOTE 1.—Loss on ignition of the pigment does not suffice for the determination of combined water in zinc chromates.

NOTE 2.—Traces of oil in the pigment should first be removed with ether.

METHODS OF CHEMICAL ANALYSIS

Solution of Sample

Dissolve 4 g. of the sample in 50 ml. of cold 6 N H_2SO_4 (160 ml. concentrated H_2SO_4 per liter of solution). It should dissolve completely at this stage. Transfer the solution to a 500-ml. calibrated flask and make up to 500 ml. The concentration of the solution should be approximately 0.1 N chromic acid.

Chromium

7. (*a*) *Special Solution Required.*—Standard sodium thiosulfate solution (0.1 N).

(*b*) *Procedure.*—To a 400-ml. beaker containing 200 ml. of water, add 2 g. of potassium iodide (solid) and 5 ml. of H_2SO_4 (sp. gr. 1.42). (Final acidity should be approximately 5 ml. of acid per 100 ml. of solution). Pipette 25 ml. of the chromic acid solution into the solution of KI and H_2SO_4 and after 5 min. titrate with the 0.1 N standard sodium thiosulfate solution, using starch as an internal indicator. The percentage of chromic acid may be calculated from the following values:

1 ml. of N sodium thiosulfate = 0.01733 g. of Cr. or 0.03334 g. of CrO_3.

Report the amount calculated as percentage of CrO_3.

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[1] Refer to Blair, "Chemical Analysis of Iron," Fig. 63, p. 138.

Zinc

8. (*a*) *Special Solution Required.*—Potassium ferrocyanide solution. The $K_4Fe(CN)_6$ solution is standardized as follows: Dissolve 42.5 g. of $K_4Fe(CN)_6$ per liter of solution. Dissolve 0.4 g. pure zinc in 25 ml. of concentrated HCl. After the zinc has completely dissolved, dilute to 300 ml. Neutralize the solution with NH_4OH, add 2 g. NH_4Cl and 3 ml. of HCl (sp. gr. 1.19). Titrate the solution with $K_4Fe(CN)_6$ using uranyl acetate as an external indicator on a spot tile and ferrous ammonium sulfate as an internal indicator. Calculate the strength of the potassium ferrocyanide solution in terms of grams of zinc as follows:

$$1 \text{ ml. of } K_4Fe(CN)_6 = \frac{\text{Grams of zinc}}{\text{Milliliters of } K_4Fe(CN)_6}.$$

(*b*) *Procedure.*—Nearly neutralize 100 ml. of the solution of the sample with NH_4OH, add methyl orange indicator and continue neutralization with weak NH_4OH (1:10) until exactly neutral. There should be no precipitate formed. The solution must be barely acid before beginning the precipitation and the acidity (due to liberated H_2SO_4) should not increase to more than 0.1 *N*. The precipitation of zinc sulfide ceases if the acidity increases to more than 550 mg. of H_2SO_4 per 100 ml. of solution; below 0.1 *N* acid concentration, the precipitation is complete. Pass H_2S through the solution at a rapid rate (at least eight bubbles per second) for at least 40 min., keeping the temperature below 50 C. Filter the solution and wash the precipitate with water.

Dissolve the ZnS precipitate in hot diluted HCl (1:3). Wash the filter paper well with hot water. Boil the H_2S out of the ZnS solution, neutralize with NH_4OH and adjust the volume to 300 ml. Add 2 g. of NH_4Cl, and 3 ml. of HCl (sp. gr. 1.19), and heat to boiling. Titrate the hot solution with standard potassium ferrocyanide solution using uranyl acetate as an external indicator on a spot plate, and 1 to 2 drops of ferrous ammonium sulfate as an internal indicator. The percentage of zinc in the specimen may be calculated from the following formula:

$$\text{Zinc, per cent} = \frac{\text{Milliliters of } K_4Fe(CN)_6 \times \text{grams of zinc per milliliter} \times 100}{\text{Weight of sample}}$$

$$\text{Zinc oxide, per cent} = \text{percentage of zinc} \times 1.2447$$

Report the amount calculated as percentage of ZnO.

Total Alkali Metals

9. Dissolve 1 g. of zinc yellow in 10 ml. of acetic acid (1:1), add 25 ml. of water and heat until completely dissolved. Dilute to approximately 250 ml. and heat the solution to boiling. Add 20 ml. of lead acetate (10 per cent) and allow to settle. Filter off the precipitate and wash well with

hot water. Saturate the filtrate with H_2S, observing the precautions as outlined in the procedure for determining zinc (Section 8 (*b*)); zinc and excess lead will be precipitated. (It is necessary to keep down the concentration of acetic acid to ensure complete removal of the zinc.) Filter and wash the precipitate with cold water. Boil the filtrate to expel H_2S, then add 3 ml. of H_2SO_4 and boil down to a small volume. Transfer the concentrate to a weighed silica dish and evaporate to dryness on a hot plate. Heat to complete dryness over a bunsen burner. Add solid $(NH_4)_2CO_3$ to the residue and heat till volatilized. Repeat the operation four times, cool the dish, and weigh. Add a few crystals of $(NH_4)_2CO_3$, and again heat the residue until volatilized. Cool, and weigh the dish and repeat the operation until constant weight is obtained.

The percentage of total alkali may be calculated as follows:

$$\text{Total sulfate } (Na_2SO_4 \text{ and } K_2SO_4)\text{, per cent} = \frac{\text{Weight of alkaline sulfates} \times 100}{\text{Weight of sample}}$$

$$\text{Total Alkali } (K_2O)\text{, per cent} = \text{percentage of } K_2SO_4 \times 0.541$$

Report the amount calculated as percentage of K_2O.

NOTE.—The above determination would include both potassium and sodium if present. Flame test for sodium should be made at this point, and if present the procedure for sodium should be followed (see Section 12 (*a*) and (*b*)).

Sulfates

10. Dissolve 1 g. of zinc yellow in 15 ml. of HCl (sp. gr. 1.19). Heat the solution to boiling and add 5 ml. of alcohol by drops to insure the reduction of chromium. Boil the solution down to a small volume. Dilute the concentrate to 300 ml. with water and neutralize with Na_2CO_3 adding 3.5 g. in excess. Heat the solution to boiling and boil to ensure the conversion of the insoluble sulfates to the soluble form. Allow the precipitate in the solution to settle on a hot plate and filter. Wash the precipitate with hot water. Neutralize the filtrate with HCl and boil to expel the CO_2. Adjust the acidity to 2.5 per cent with HCl and add drop-by-drop 15 ml. of barium chloride (20 per cent) to the solution, keeping the latter boiling. Allow the precipitate to settle on a hot plate, filter through a weighed Gooch crucible, wash, dry, ignite, cool, and weigh. The increase in weight represents the barium sulfate.

$$\text{Sulfate, per cent} = \frac{\text{Weight } BaSO_4 \times 0.343 \times 100}{\text{Weight of sample}}$$

Report the amount calculated as percentage of SO_3.

Chlorine

11. Dissolve 1 g. of zinc yellow in 20 ml. of H_2SO_4 (2:3) and heat the solution to boiling. Add drop-by-drop 5 ml. of alcohol to the boiling solution; reduction of the chromium is complete when a clear green solution

is obtained. Dilute the solution to approximately 250 ml., neutralize with Na_2CO_3 and add a slight excess. Boil the solution a few minutes, filter, and wash. Acidify with diluted HNO_3 (1:1), adding 25 ml. in excess. Add 10 ml. of standard silver nitrate solution (0.05 N) and titrate the excess silver nitrate with standard potassium sulfocyanate (0.05 N), using ferric sulfate as an internal indicator. A red tinge in the solution indicates the end point. The percentage of chlorine in the sample may be calculated as follows:

$$\text{Chlorine, per cent} = \frac{\begin{array}{c}\text{milliliters of AgNO}_3 - (\text{milliliters of KCNS} \times \text{factor}) \\ \times \text{ grams of Cl per milliliter of AgNO}_3 \times 100\end{array}}{\text{Weight of sample}}$$

Report the amount calculated as percentage of chlorine.

Sodium

12. (*a*) *Special Solutions Required.*—Double acetate solution, prepared as follows:

Solution A	Uranyl acetate	10 g.
	Acetic acid (30 per cent)	6 g.
	Water	65 g.
Solution B	Zinc acetate	30 g.
	Acetic acid (30 per cent)	3 g.
	Water	65 g.

When the above solutions A and B are each completely dissolved, mix them, and allow to cool to 20 C. ± 1 C. Keep the resulting solution at this temperature for several hours. Filter off the triple salt which crystallizes out and which may be assumed to be saturated with respect to sodium at 20 C. since the reagent usually contains sufficient sodium to give a precipitate.

(*b*) *Procedure.*—Proceed as in the determination of total alkali (Section 9) to the weighed sulfates. Dissolve the sulfates in 10 to 15 ml. of water. Add to the solution 100 ml. of zinc-uranyl acetate reagent and allow to stand at 20 C. ± 1 C. for 30 to 45 min. stirring occasionally. (Scratch the side of the beaker occasionally to start crystallization.) Filter the solution through a tared Gooch crucible and wash with five successive amounts of 2 ml. of zinc-uranyl acetate reagent, then with five 2-ml. portions of alcohol (previously saturated with sodium zinc-uranyl acetate) and finally with ether. Dry at 40 C. for 10 to 15 min., and weigh. The percentage of sodium may be calculated as follows:

$$\text{Sodium, per cent} = \frac{\text{Weight of precipitate} \times 0.01495 \times 100}{\text{Weight of sample}}.$$

NOTE.—The precipitate is slightly soluble in water, insoluble in the precipitant, alcohol, and ether. Barium, calcium, magnesium, and zinc do not interfere with the precipitation. Potassium has little effect if less than 0.05 g. is present; lithium, phosphates, oxalates, and tartrates should be absent.

Calcium

13. Proceed as in the determination of sulfates (Section 10) to the acidification of the sodium carbonate solution. Make the solution ammoniacal and then slightly acid with acetic acid. Add 15 ml. of saturated ammonium acetate solution and again make ammoniacal with NH_4OH and allow to stand on a hot plate over night. Filter off any precipitate in the morning. Wash free from oxalates with NH_4OH (10 per cent). Dissolve the oxalate precipitate in hot diluted H_2SO_4. Dilute the solution to approximately 300 ml. and add 10 ml. of H_2SO_4. Heat the solution to boiling and titrate with 0.1 N potassium permanganate solution.

$$\text{Calcium, per cent} = \frac{\text{Milliliters of } KMnO_4 \times N \times 0.20}{\text{Weight of sample}} \times 100$$

where N = the normality of the $KMnO_4$ solution.

Ammonia[1]

14. Distill 1 g. of the zinc yellow pigment with NaOH solution expelling the ammonia and collecting it in a known excess of 0.1 N H_2SO_4. Titrate the excess H_2SO_4 with 0.1 N NaOH.

EXPLANATORY NOTES

NOTE 1.—According to the work of Denslow, it appears probable that zinc yellow is a definite salt, the "oxide formula" of which would be $K_2O \cdot 4ZnO \cdot 4CrO_3 \cdot 3H_2O$.

NOTE 2.—For ordinary routine work, the following determinations should be sufficient: combined water, chromium (CrO_3), zinc (ZnO), total alkali metals (K_2O) and sulfates (SO_3). These should give a summation close to 100 per cent.

NOTE 3.—In commercial "zinc yellow" pigments, using the above described methods, the percentage of zinc calculated as ZnO generally varies between 36.9 and 37.8. The chromium as CrO_3 generally varies between 41.3 and 43.6 per cent. The sulfates as SO_3 generally vary between 1.4 and 3.3 per cent. The "combined water" generally varies between 6.1 and 6.7 per cent. The alkali metals expressed as K_2O generally vary between 10.4 and 11.8 per cent. One sample showed 0.17 per cent moisture and 0.51 per cent sodium expressed as Na_2O.

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[1] This procedure is occasionally but not usually employed for preparing zinc yellow pigments.

TENTATIVE METHOD OF ROUTINE ANALYSIS
OF
DRY CUPROUS OXIDE[1]

A.S.T.M. Designation: D 283 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. This method covers the chemical analysis of the pigment, dry cuprous oxide.

Treatment of Sample

2. Dry pigments, if lumpy or not finely ground, shall be ground to a fine powder and thoroughly mixed (Note 1). Large samples may be thoroughly mixed and a representative portion taken and powdered, if lumpy or not finely ground. The sample in all cases shall be thoroughly mixed before taking portions for analysis. All samples shall be preserved in stoppered bottles or containers (Note 2). Commercial copper oxides appear to segregate rather easily. Therefore, the thorough mixing of the sample to insure homogeneity is an extremely important factor in obtaining concordant results.

TOTAL COPPER

Total Copper

3. Weigh accurately a dry sample of from 0.15 to 0.2 g. of the material, transfer it to a 250-ml. beaker, add 10 to 15 ml. of HCl (sp. gr. 1.19) and 1 to 2 ml. of HNO_3 (sp. gr. 1.42) and boil for several minutes. Add 10 ml. of H_2SO_4 (sp. gr. 1.84) and heat until copious fumes of sulfuric acid are evolved. Cool, add cautiously while stirring, 50 ml. of cold water, and boil to dissolve the sulfates. Cool, filter off any insoluble matter (SiO_2, $PbSO_4$, etc.) and wash the filter and residue until free from copper, with a cold H_2SO_4 solution (1 to 2 per cent), catching the filtrate and washings in a 250-ml. beaker, keeping the total volume of the solution down to about 150 ml. Place in the solution a piece of clean, pure sheet aluminum having a minimum purity of 99.80 per cent and to contain a maximum of 0.02 per cent copper. The sheet aluminum is convenient to use in the form of a cylinder about 3.5 to 4 cm. in diameter by 3.5 to 4 cm. in height, with a

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

This method is in effect a tentative revision of and is intended to supersede when adopted the present Standard Method of Routine Analysis of Dry Cuprous Oxide (A.S.T.M. Designation: D 283 - 36), 1936 Book of A.S.T.M. Standards, Part II, p. 624.

small extending piece about 7 to 8 cm. in height as a means of removing the cylinder. Cover the beaker and heat to gentle boiling for about 30 min. or until the copper is completely precipitated as a metallic sponge on the aluminum. Thoroughly wash the copper sponge from the aluminum into a 250-ml. beaker and carefully examine the aluminum sheet for any remaining particles of copper. Wash the copper sponge several times by decantation with hot water, filtering the wash water through a 9-cm. filter paper, but retaining the copper as completely as possible in the beaker. The filtrate and washings may be discarded or used for the determination of iron, if present (Note 4). Add from 10 to 15 ml. of ferric chloride-hydrochloric acid solution (prepared by dissolving 250 g. of $FeCl_3 \cdot 6H_2O$ in 500 ml. of HCl (1:1)), on the filter paper, catching this in the beaker containing the copper sponge. The copper generally dissolves in a few minutes without the need of heating. Break up any large particles of the copper sponge with a stirring rod. When the copper is completely dissolved, wash the filter thoroughly with cold water and finally, dilute the filtrate to about 200 ml. with cold water, add 5 ml. of syrupy phosphoric acid, then 3 drops of indicator and titrate the cold solution at once with 0.1 N $K_2Cr_2O_7$ solution (1 ml. of 0.1 N $K_2Cr_2O_7$ is equivalent to 0.0032 g. Cu.).

METALLIC COPPER AND CUPROUS OXIDE[1]

Apparatus

4. *Filter.*[2]—The filter consists of a 55-mm. filter tube of the type used for small Gooch crucibles. In the opening is placed a perforated porcelain button which is seated at right angles to the stem. An asbestos pad is built up over the button and securely set by tamping with a glass rod. The filter must be packed in such a way that the tube may be held in an inverted position without dislodging either the disk or the pad. It has been found that a tube about 60 by 25 mm., with a stem 110 mm. in length, is a convenient size. A 20-mm. Gooch crucible button serves to support the asbestos pad.

Special Solutions Required

5. (*a*) *Extraction Solution.*—Dissolve 6 g. of c. p. hydrazine sulfate in 1 liter of NH_4OH (sp. gr. 0.90).

(*b*) *Ferric Chloride Solution.*—Add 150 g. of $FeCl_3 . 6H_2O$ and 300 ml. of HCl (sp. gr. 1.19) to 800 ml. of air-free, carbon-dioxide-saturated water.

(*c*) *Indicator.*—Shake 2 g. of barium diphenylamine sulfonate,[3] 50 ml. of carbon-dioxide-saturated distilled water, and 5 g. of sodium sulfate until a uniform suspension of barium sulfate is obtained. Dilute the suspension with 50 ml. of water and allow to settle. When clear, decant the supernatant liquid through a filter and preserve in a dark bottle.

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[1] L. C. Hurd and A. R. Clark, "Determination of Metallic Copper in Cuprous Oxide - Cupric Oxide Mixture," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 8, No. 5, p. 380 (1936).

[2] For further information on the filter see W. Geilman, and F. Z. Weibke, *Zeitschrift für anorganische und allgemeine Chemie*, Vol. 199, p. 120 (1931).

[3] Barium diphenylamine sulfonate may be obtained from the Eastman Kodak Co.

(*d*) *Phosphoric Acid.*—Prepare a solution of ortho-phosphoric acid, 85 per cent reagent, conforming to specifications of the American Chemical Society.

(*e*) *Potassium Bichromate Solution* (0.1 *N*).—Prepare a 0.1 *N* solution by dissolving 4.903 g. of reagent quality potassium bichromate in water, diluting to 1 liter.

(*f*) *Water.*—Boil vigorously distilled water for several minutes and allow to cool in an atmosphere of carbon dioxide. Allow a slow current of the gas to pass continuously through the storage bottle.

Metallic Copper

6. (*a*) Weigh accurately a sample of suitable size on a small watch-glass, and place the glass and contents in a dry, wide-mouth 250-ml. Erlenmeyer flask. If the material is an electrolytic product low in copper, it is advisable to take a 1 to 2-g. sample. If it is from a "thermal process," the percentage of copper is usually large and a smaller sample will suffice. Displace the air in the flask with carbon dioxide (15 to 20 cu. ft. per hr.) and add 10 ml. of ethyl alcohol to dissolve any oil present in the sample. Without interrupting the flow of gas, add 150 ml. of extraction solution (Note 5). Break up any lumps of oxide with a stirring rod by gentle stirring (grinding of the sample with the stirring rod is not necessary). Violent agitation and swishing of the solution should be avoided. The carbon dioxide inlet should be about 5 cm. (2 in.) above the surface of the liquid (Note 6). The time required for complete solution of all cuprous oxide varies between 1 and 7 min. depending upon the amount and character of the sample under investigation.

(*b*) When the cuprous oxide has completely dissolved, as evidenced by the total disappearance of red particles, connect the filter to a suction and slowly lower it into the flask. As soon as the bulk of the solution is removed, rinse the flask with carbon-dioxide-saturated water and continue the filtration and washing. Five of six 100-ml. portions of wash water will suffice to remove all the original extraction solution containing the dissolved cuprous oxide. It is not necessary that the final wash water remaining in the filter tube be entirely removed. Then disconnect the filter and push the pad and contents back into the flask with a glass rod. Add 15 ml. of ferric chloride solution and warm the flask on a hot plate to just below the boiling point of the solution to dissolve the cupric oxide - copper residue. When all particles have disappeared, cool the solution to below 40 C. and add 10 ml. of phosphoric acid and 3 drops of indicator. Titrate (in an atmosphere of CO_2) the solution by running the bichromate solution into the flask. The end point is evidenced by a change from pea green to an intense purple color.

(*c*) *Calculation.*—Calculate the percentage of copper present (Note 7) from the following formula:

$$\text{Copper, per cent} = \frac{\text{Normality of } K_2Cr_2O_7 \times \text{milliliters of } K_2Cr_2O_7 \times 0.03179}{\text{Weight of sample in grams}} \times 100$$

Cuprous Oxide

7. Dissolve a 0.2-g. sample in ferric chloride and titrate the ferrous iron produced with potassium bichromate in the manner described. It is essential that the solution of the sample be carried out in an atmosphere of carbon dioxide or other inert gas. From the volume of bichromate solution equivalent to both cuprous oxide and copper, calculate the true percentage of cuprous oxide in the sample according to the following formulas:

Let

$$\frac{\text{ml.}_1}{\text{w}_1} = \text{milliliters required for copper in 1 g. of sample, and}$$

$$\frac{\text{ml.}_2}{\text{w}_2} = \text{milliliters required for copper plus cuprous oxide in 1 g. of sample.}$$

Then

$$\frac{\text{ml.}_2}{\text{w}_2} - \frac{\text{ml.}_1}{\text{w}_1} = \text{milliliters required for cuprous oxide in 1 g. of sample, and}$$

Therefore

$$\text{Cuprous oxide, per cent} = \left(\frac{\text{ml.}_2}{\text{w}_2} - \frac{\text{ml.}_1}{\text{w}_1}\right) 0.07157 \times N \text{ of } K_2Cr_2O_7 \times 100$$

but

$$\frac{\text{ml.}_1}{\text{w}_1} = \frac{\text{Percentage of copper}}{N \text{ of } K_2Cr_2O_7 \times 0.03179 \times 100}$$

Therefore

$$\text{Cuprous oxide, per cent} = \left(\frac{\text{ml.}_2}{\text{w}_2} - \frac{\text{Percentage of copper}}{N \text{ of } K_2Cr_2O_7 \times 0.03179 \times 100}\right) \times 0.07157 \times N \text{ of } K_2Cr_2O_7 \times 100$$

The calculation of the percentage of cuprous oxide is simplified if the sample taken for the copper determination be a simple multiple of that in the oxide analysis. In actual practice it has been found that a 1.000-g. sample for metallic copper and a 0.2000-g. sample for cuprous oxide are of convenient size. In this case one-fifth of the volume of bichromate used in the determination of metallic copper is subtracted from the total titration of the smaller sample to give the volume of bichromate actually equivalent to the cuprous oxide in the sample.

Report

8. Report the metallic copper (Cu) and the cuprous oxide (Cu_2O). Subtract the copper equivalents from the percentage of total copper as determined in Section 2, calculate the remainder to cupric oxide and report as percentage of CuO ($Cu \times 1.252 = CuO$).

EXPLANATORY NOTES

NOTE 1.—It is very important that the sample be thoroughly mixed. Some samples of cuprous oxide are not homogeneous, and for this reason are likely to give trouble when an attempt is made to obtain concordant results. By placing a few grams of a sample on a sheet of white paper, and drawing it out with a spatula, it is frequently found that the sample contains coarse particles of black scale, along with small balls of bright red cuprous oxide. Thus it may be necessary to grind such a product thoroughly in a mortar and pestle, in order to get it homogeneous. It is possible that during this operation a slight oxidation may take place.

NOTE 2.—Caution should be used in protecting the sample from oxidation.

NOTE 3.—A microscopic examination is helpful in showing the presence of metallic Cu, red Cu_2O, and CuO. Washing some of the sample through a fine sieve (No. 325) may reveal the presence of metallic copper retained on the sieve.

NOTE 4.—Commercial cuprous oxides may contain moisture and small amounts of iron, chlorine, oil, and acid insoluble matter.

NOTE 5.—If the ammonium hydroxide-hydrazine sulfate solution is allowed to stand in contact with the samples for more than 10 min., the loss in copper may amount to more than 2 mg.

NOTE 6.—Care must be taken not to allow the extraction solution to become saturated with carbon dioxide. The gas inlet to the flask should not be placed beneath the surface of the liquid, to avoid solubility errors.

NOTE 7.—Commercial samples of cuprous oxide have shown from 0.22 to 11.8 per cent Cu.

TENTATIVE METHOD OF TEST
FOR
REACTIVITY OF PAINT LIQUIDS[1]

A.S.T.M. Designation: D 479 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method is intended for determining the reactivity between paint liquids and zinc oxide.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—Balance or scale sensitive to 1 g.

(*b*) *Containers.*—Friction-top cans.

(*c*) *Spatulas.*—Spatulas or suitable paddles.

(*d*) *Thermometer.*—Thermometer graduated from 0 to 100 C. and accurate to 0.5 C.

(*e*) *Paint Mixing Equipment* (Optional).—Laboratory paint mixer or stirrer.

(*f*) *Consistency Measuring Apparatus* (Optional).—Mobilometer, viscosimeter, plastometer or viscosity cup.

Materials

3. The following materials will be required:

(*a*) *Paint Liquid.*—Varnishes, resin solutions, or other liquids used in the manufacture of paints, enamels, and lacquers are considered as paint liquids. If the viscosity of the liquid to be tested is such that dilution is necessary, the liquid reduced in a manner mutually agreed upon by the purchaser and the seller shall be used in the test.

(*b*) *Zinc Oxide.*—A standard Green Seal zinc oxide or other zinc oxide mutually agreed upon by the purchaser and the seller.

Reactivity Determination

4. The zinc oxide and paint liquid in a ratio of 35 to 65 by weight, respectively, shall be mixed to a uniform paint. Usually 210 g. of zinc oxide and 390 g. of paint liquid are ample. The zinc oxide and paint liquid shall be mixed by alternately adding portions of the pigment and liquid. The additions shall be regulated so that a fairly stiff paste is produced.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products.

After all the pigment and sufficient liquid have been added to produce a paste, the paste shall be reduced to a paint by gradually working in the remainder of the liquid. The total mixing operation shall not take longer than 30 min. The mixing may be done in a suitable container by hand with a stiff spatula or a paddle, or with a suitable mechanical mixer. The temperature of the paint shall then be brought to 25 ± 0.5 C. and its consistency determined by a method mutually agreed upon by the purchaser and the seller, which may include visual inspection with a spatula, or any of the usual instruments, such as the Gardner mobilometer or the Stormer viscosimeter. Limits for the consistency of the fresh paint shall be agreed upon by the purchaser and the seller. The paint shall then be transferred to a friction-top can and stored under normal room conditions. The can shall be filled to within at least $\frac{1}{4}$ in. of the top and the lid tightly inserted. After 24-hr. storage and again after 5-day storage (Note) the paint shall be thoroughly mixed, brought to 25 ± 0.5 C. and the consistency determined, using the same procedure as used in determining the consistency of the fresh paint.

NOTE.—Preliminary indications of the reactivity of the liquid are obtained after 24-hr. storage, but final decision should be made following the consistency determination after the 5-day storage. By mutual agreement between the purchaser and the seller, any specific period of storage may be used.

Grading

5. The paint liquid shall be graded as nonreactive, slightly reactive, moderately reactive, or reactive, in accordance with the following:

(*a*) *Nonreactive.*—If the consistency of the aged paint is the same or less than that of the fresh paint, the liquid shall be graded as nonreactive.

(*b*) *Slightly Reactive.*—If on aging the consistency increased slightly but not sufficiently to be of practical significance, the liquid shall be graded as slightly reactive.

(*c*) *Moderately Reactive.*—If on aging the consistency definitely increased but the product would still be usable, the liquid shall be graded as moderately reactive.

(*d*) *Reactive.*—If on aging the paint bodied objectionably, livered or gelled, the liquid shall be graded as reactive. The purchaser and the seller shall agree on the maximum increase in consistency that will be allowed.

TENTATIVE METHODS OF SAMPLING AND GRADING ROSIN[1,2]

A.S.T.M. Designation: D 509 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These methods are intended for use in sampling rosin in solid mass and in original barrels and drums for the purpose of determining the grade of the rosin.

Apparatus

2. The apparatus required for sampling and grading is illustrated in Fig. 1.

Sampling

3. (*a*) *Number of Packages to Be Sampled and Graded.*—For an original (first) grading, each package of rosin shall be sampled and graded. For regrading, to check the correctness of an original grading, a preliminary sampling of not less than 20 per cent of the entire lot or shipment shall be made. If the grades of more than 15 per cent of these preliminary samples differ from the grade requirements for the rosin as indicated by the grade marks on the packages additional packages in the lot shall be sampled so that the total number of packages sampled is not less than 50 per cent of the lot, and preferably all the packages shall be sampled and graded (Note 1).

(*b*) *Method of Sampling.*—Samples for grading shall be taken in the following manner (Note 2): A lump approximately 4 to 6 in. in diameter shall be removed by spiking the rosin in the package with a pointed, heavy iron bar, so that the top of the lump comes from not less than 6 in. (4 in. for drums having permanent heads) below the surface of the rosin. A specimen for grading shall be cut from the sample lump with a rosin adz or other suitable tool. The grading specimen shall be approximately cubical in shape, and $\frac{7}{8}$ in. in thickness in the direction or dimension through which it is viewed or graded (Note 3).

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-17 on Naval Stores.

[2] These methods of sampling and grading rosin are identical in substance with the methods recommended and used by the Food and Drug Administration, U. S. Department of Agriculture, in the administration of the U. S. Naval Stores Act.

Grading

4. *(a)* The grade of the rosin shall be determined by comparing the specimen with the appropriate U. S. standard types for rosin, or suitable type samples made from rosin selected to match the U. S. standard types. The grade is that of the highest standard which the specimen is equal to or lighter than, in color (Note 4). If the color of the rosin is, without doubt, darker than that of a standard, the rosin shall take the grade of the next lower standard. If, however, the color is such that a qualified grader is unable to conclude definitely whether the color of the rosin is or is not equal to that of the standard with which it is compared, then the rosin shall be assigned the grade of such standard (Note 5).

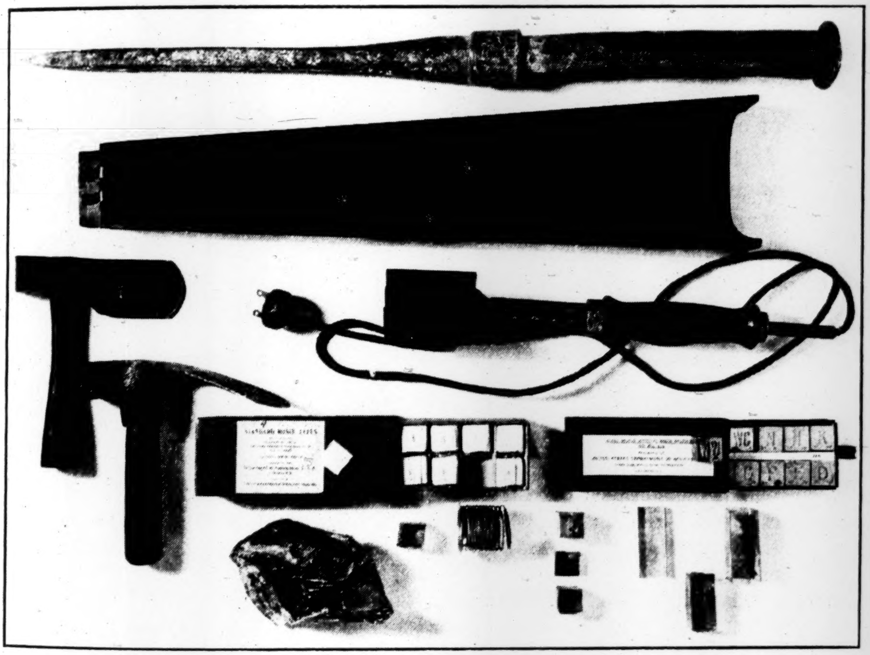

FIG. 1.—Apparatus for Sampling and Grading Rosin.

(b) A package of rosin containing two or more grades shall take the grade of the darkest rosin found therein; provided, that when a package is also sampled from close to the bottom head, a difference of one grade between top and bottom samples shall be allowed, and the package shall be graded on the basis of the top sample. If the difference is more than one grade the bottom-head sample shall determine the grade of the package of rosin.

(c) Rosin which is slightly opaque (caused by occluded moisture or formation of crystals in the solid mass) shall be graded in the usual way

if the condition permits an accurate evaluation of the color (hue, saturation, and brightness) in comparison with the standards. If, however, the opaqueness is of such a degree that an accurate determination of grade in accordance with the standards is not possible, the rosin shall be designated "OPAQUE" and graded "OP," in which case its acceptance and value shall be a matter for settlement between the purchaser and the seller.

Tolerance[1]

5. (*a*) Careful competent graders rarely get exact duplicate results on all individual samples when regrading a large number of rosin samples. Furthermore, there is always to be considered the possibility that a second sample from a package, taken from a different position in the package, at a different time, and after the rosin might have been exposed to weathering conditions for an indefinite period, may be slightly lighter or darker than the original sample. An allowance shall therefore be made when regrading any lot of rosin.

(*b*) If a regrading discloses a variation from the original grading, but the packages found to be off grade comprise not more than 15 per cent of the number sampled, with none more than one grade off, the original grading shall be considered as confirmed.

EXPLANATORY NOTES

NOTE 1.—Gum rosin, that is, rosin made from the gum or oleoresin that has exuded from the living tree, is ordinarily made in batches of from 6 to 8 barrels or drums, weighing from 475 to 600 lb. each. A sample drawn from any one package cannot be expected to represent more than the 6 or 8 barrels or drums comprising the batch of which the sampled package was a part. The color value of the rosin in any one batch, after the rosin has been packaged, may show enough variation, due to several factors, to result in a difference in grade (usually not more than one grade) as between different barrels of the batch. The packages comprising a lot of rosin moving or that has moved in commerce from a large concentration and distributing point may represent the production of a number of different producers from widely separated localities, and from gum collected at different seasons of the year, and may also have been graded by a number of different graders. The difficulty of obtaining a correct appraisal of the grading of an entire lot of rosin from a too limited number of samples is thus apparent.

NOTE 2.—Sampling for original grading at the still or primary market concentration yard is also effected by the use of one of several kinds of sampling molds. In one instance the mold is suspended, by means of a coiled wire or string, in the hot molten rosin to a depth of about 6 in. below the surface of the hot liquid rosin when the package is filled. In another procedure a specially designed sampling-mold assembly is fastened in place in the container through an opening in the side before the package is filled. In either case, the mold or sampler remains in place in the package until after the rosin has cooled and solidified. To grade, the sampler is removed either by careful spiking, in the case of the suspended mold, or by pulling it out of the casing which remains in the package, in the case of the side sampler device. For further details on sampling, reference may be made to the Regulations for the Enforcement of the Naval Stores Act, available on application to U. S. Department of Agriculture.

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[1] The statement covering tolerance presented herewith is not an official pronouncement of the U. S. Food and Drug Administration under the U. S. Naval Stores Act.

NOTE 3.—If any sample of rosin for grading is too large or has too irregular or uneven surfaces, it should be brought to the correct size of ⅞ in. by repeatedly gently rubbing it, for short periods at a time, against the surface of a suitably designed "smoothing iron" or hot flat iron. Before each application of the sample to the iron, wipe off any adhering hot rosin remaining on the iron from the previous application.

NOTE 4.—The "color" of a sample of rosin is made up of three attributes: hue, saturation, and brightness. "Hue" alludes to the characteristic described by the words "yellow" or "red." "Saturation" describes the purity or strength of the yellowness or redness of the color. "Brightness" depends on the relative amount of light transmitted by the rosin. The cleanliness of the rosin affects its transparency and therefore its brightness. The terms "lighter than" and its inverse, "darker than" are convenient to describe the difference between a sample and a standard. The rosin may be darker than the standard in one or more of the following ways: (*1*) a redder hue, (*2*) a more saturated hue, and (*3*) a lower brightness.

NOTE 5.—When a grader is satisfied that the color of a rosin is definitely darker than the *WW* standard, for example, but lighter than the *WG* standard, the rosin is to be graded *WG*. If, however, the grader cannot definitely decide whether the color of the rosin is equal to or is darker than that of the *WW* standard, it should be graded *WW*.

Tentative Specifications for

FUEL OILS[1]

A.S.T.M. Designation: D 396 – 38 T

Issued, 1934; Revised, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover five grades of fuel oil for various types of fuel-oil-burning equipment.

General Requirements

2. The fuel oils herein specified shall be hydrocarbon oils free from acid, grit and fibrous or other foreign matter likely to clog or injure the burner or valves. If required, the oil shall be strained by being drawn through filters or wire gauze of 16 meshes to the inch.[3] The clearance area through the strainers shall be at least twice the area of the suction pipe, and the strainers shall be in duplicate.

Detailed Requirements

3. The various grades of fuel oil shall conform to the detailed requirements shown in Table I.

Methods of Testing

4. The requirements enumerated in these specifications shall be determined in accordance with the following methods of testing of the American Society for Testing Materials, except as may be required under Paragraph (*a*):

(*a*) *Flash Point.*—Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93),[4] except where other methods are prescribed by law for the determination of minimum flash point.

(*b*) *Pour Point.*—Standard Method of Test for Cloud and Pour Points (A.S.T.M. Designation: D 97).[5]

(*c*) *Water and Sediment.*—The water and sediment in Grades Nos. 1, 2, 3 and 5 shall be determined in accordance with the Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (A.S.T.M. Designation: D 96);[6] and in Grade No. 6 by the Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (A.S.T.M. Designation: D 95);[7] and the Tentative Method of Test for Sediment in Fuel Oil by Extraction (A.S.T.M. Designation: D 473).[8]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

The Commercial Standard Specifications for Fuel Oils (CS 12 – 38) of the U. S. Department of Commerce conform in substance with these specifications but differ as to the form and arrangement.

[2] Revision accepted by Committee E-10 on Standards, April 27, 1938.

[3] For detailed requirements for the wire gauze see those prescribed for the U. S. Standard No. 16 (1190-micron) sieve in the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, p. 1289.

[4] 1936 Book of A.S.T.M. Standards, Part II, p. 897.

[5] *Ibid.*, p. 853.

(*d*) *Carbon Residue.*—Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (A.S.T.M. Designation: D 189).[9]

TABLE I.—DETAILED REQUIREMENTS FOR FUEL OILS.[a]

Grade of Fuel Oil[b]	Flash Point, deg. Fahr.		Pour Point, deg. Fahr.	Water and Sediment, per cent	Carbon Residue, per cent	Ash, per cent	Distillation Temperatures, deg. Fahr.				Viscosity, sec.			
							10 per cent Point	90 per cent Point		End Point	Saybolt Universal (at 100 F.)		Saybolt Furol (at 122 F.)	
	Min.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Min.
No. 1 A distillate oil for use in burners requiring a volatile fuel...	100 or legal	165	15[c]	trace	0.05[d] on 10 per cent residuum	....	410	...	...	560[e]	...	...	...	...
No. 2 A distillate oil for use in burners requiring a moderately volatile fuel.........	110 or legal	190	15[c]	0.05	0.25[f] on 10 per cent residuum	....	440	600	...	...	...	...	...	...
No. 3 A distillate oil for use in burners requiring a low-viscosity fuel...	110 or legal	230	20[c]	0.10	0.15	....	...	675	600[g]	...	55	...	...	...
No. 5 An oil for use in burners requiring a medium-viscosity fuel..	130 or legal	...	...	1.00	....	0.10	...	...	...	...	...	60	40	...
No. 6 An oil for use in burners equipped with preheaters permitting a high-viscosity fuel..............	150	...	...	2.00[h]	....	....	...	...	...	...	...	...	300	45

[a] Recognizing the necessity for low-sulfur fuel oils used in connection with heat-treatment, non-ferrous-metal, glass and ceramic furnaces and other special uses, a sulfur requirement may be specified in accordance with the following table:

GRADE OF FUEL OIL	SULFUR, MAX., PER CENT
No. 1	0.5
No. 2	0.5
No. 3	0.75
No. 5	no limit
No. 6	no limit

Other sulfur limits may be specified only by mutual agreement between the purchaser and the seller.

[b] It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

[c] Lower or higher pour points may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 0 F. under any conditions.

[d] The carbon residue on 10 per cent residuum may be increased to a maximum of 0.12 per cent when this oil is to be used in other than sleeve-type blue-flame burners. This limit may be specified by mutual agreement between the purchaser and the seller.

[e] The maximum end point may be increased to 590 F. when this oil is to be used in other than sleeve-type blue-flame burners.

[f] To meet certain burner requirements, the carbon-residue limit on this oil may be reduced to 0.15 per cent on 10 per cent residuum.

[g] This requirement may be waived if the A.P.I. gravity is 26 or lower.

[h] The amount of water by distillation plus the sediment by extraction shall not exceed 2.00 per cent. The amount of sediment by extraction shall not exceed 0.50 per cent. A deduction in quantity shall be made for all water and sediment in excess of 1.0 per cent.

The 10 per cent residuum for the determination of carbon residue in Grades Nos. 1 and 2 shall be obtained by the following adaptation of the distillation procedure described in Sections

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[6] 1936 Book of A.S.T.M. Standards, Part II, p. 1001.

[7] *Ibid.*, p. 997.

[8] See p. 813.

[9] 1936 Book of A.S.T.M. Standards, Part II, p. 849.

2 (*j*) to 4 of the Standard Method of Test for Distillation of Gas Oil and Similar Distillate Fuel Oils (A.S.T.M. Designation: D 158):[10]

The 200-ml. graduate used to measure the initial sample shall be used, without cleaning, to receive the distillate. The temperature at the condenser outlet shall be maintained at 32 to 40 F. (0 to 4.45 C.) throughout the distillation in the case of products having a distillation end point below 600 F. (315 C.). The standard condenser temperature of 90 to 100 F. (32.2 to 37.8 C.) shall be maintained for products having end points above 600 F. (315 C.) or in those cases where waxy distillates are obtained. The oil shall be distilled at the rate prescribed until exactly 178 ml. has been collected in the graduate, then the heating shall be discontinued and the condenser allowed to drain until 180 ml. (90 per cent of the charge to the flask) has been collected in the graduate. The graduate shall be replaced by a small Erlenmeyer flask and any final drainings caught in this flask. To this Erlenmeyer flask shall be added, while still warm, the residue left in the distillation flask and the contents shaken well. The contents of the Erlenmeyer flask then represents a 10 per cent residuum from the original product. While warm enough to flow freely, approximately 10 g. of the residuum shall be poured into the weighed crucible to be used in the carbon-residue test. After cooling, the sample shall be accurately weighed and the carbon residue determined in accordance with the Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (A.S.T.M. Designation: D 189).[9] The percentage of carbon residue in the residuum shall be reported as "carbon residue on 10 per cent residuum."

NOTE.—It is important that a clean distillation flask be used for each test.

(*e*) *Ash*.—Tentative Method of Test for Ash Content of Petroleum Oils (A.S.T.M. Designation: D 482).[11]

(*f*) *Distillation*.—Distillation of Grade No. 1 oil shall be determined in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86),[12] and of Grades Nos. 2 and 3 in accordance with the Standard Method of Test for Distillation of Gas Oil and Similar Distillate Fuel Oils (A.S.T.M. Designation: D 158).[10]

(*g*) *Viscosity*.—Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88).[13]

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[10] 1938 Supplement to Book of A.S.T.M. Standards, p. 144.

[11] See p. 865.

[12] 1938 Supplement to Book of A.S.T.M. Standards, p. 137.

[13] *Ibid*., p. 148.

Tentative Specifications for
STODDARD SOLVENT[1]

A.S.T.M. Designation: D 484 - 38 T

Issued, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover a grade of petroleum distillate of low flammability used in dry cleaning.

General Requirements

2. Stoddard solvent shall be a petroleum distillate, clear and free from suspended matter and undissolved water, and free from rancid and objectionable odor. The odor shall be typical of a "sweet" refined naphtha.

Detailed Requirements

3. Stoddard solvent shall conform to the following detailed requirements:

Color	water-white or not darker than 21
Corrosive properties	not more than extremely slight discoloration on a clean copper strip submerged in the solvent for 3 hr. at 212 F. (100 C.)
Doctor test	negative
Sulfuric-acid absorption, max., per cent	5
Flash point, min., deg. Fahr.	100
Distillation:	
Percentage recovered at 350 F. (176 C.), min.	50
Percentage recovered at 375 F. (190 C.), min.	90
End point, max., deg. Fahr.	410
Residue, max., per cent	1.5
Acidity	no acid reaction to methyl orange shown by residue from distillation

Methods of Testing

4. The requirements enumerated in Section 3 shall be determined in accordance with the following methods of test:

(*a*) *Color.*—Standard Method of Test for Color of Refined Oils by Means of the Saybolt Chromometer (A.S.T.M. Designation: D 156) of the American Society for Testing Materials.[2]

(*b*) *Corrosive Properties.*[3]—Place a clean strip of mechanically polished pure sheet copper about ½ in. in width and 3 in. in length in a clean test tube. Add enough of the sample to be tested to cover the strip completely. Close the tube with a vented stopper and maintain for 3 hr. at 212 F. (100 C.). Rinse the copper strip with sulfur-free acetone and compare it with a similar strip of freshly polished copper. Discoloration or pitting indicates corrosion.

(*c*) *Doctor Test:*

Preparation of Doctor (*Sodium Plumbite*) *Solution.*—Dissolve approximately

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] 1938 Supplement to Book of A.S.T.M. Standards, p. 134.

[3] This test for corrosive properties is identical with Method 530.31 of the Federal Specification for Lubricants and Liquid Fuels; General Specifications (Methods for Sampling and Testing) (VV-L-791a), p. 126.

125 g. of sodium hydroxide in 1 liter of distilled water. Add 60 g. of litharge and shake vigorously for 15 min., or let stand with occasional shakings for at least a day. Allow to settle and decant or siphon off the clear liquid. Filtration through a mat of asbestos may be employed if the solution does not settle clear. The solution should be kept in a tightly corked bottle and should be refiltered before use if not perfectly clear.

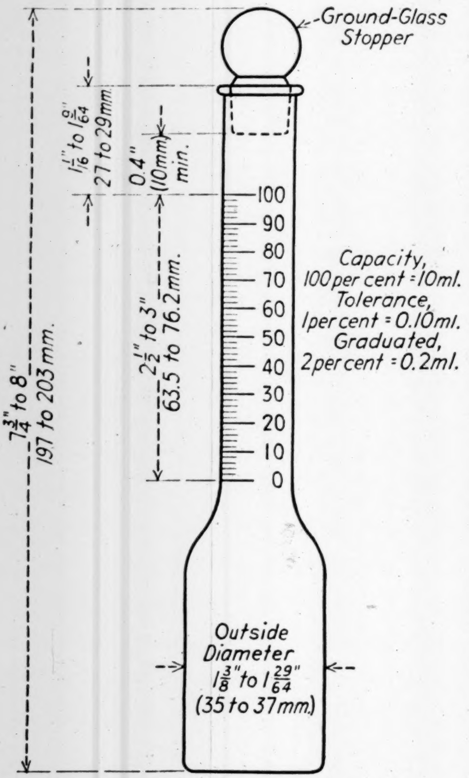
Ground-Glass Stopper
$1\frac{1}{16}$" to $1\frac{9}{64}$" 27 to 29mm
0.4" (10mm) min.
100
90
80
70
60
50
40
30
20
10
0
Capacity, 100 per cent = 10ml.
Tolerance, 1 per cent = 0.10ml.
Graduated, 2 per cent = 0.2ml.
$2\frac{1}{2}$" to 3" 63.5 to 76.2mm.
$7\frac{3}{4}$" to 8" 197 to 203 mm.
Outside Diameter $1\frac{3}{8}$" to $1\frac{29}{64}$" (35 to 37mm)

FIG. 1.—Modified Babcock Bottle.

Procedure.—Shake vigorously together in a test tube 10 ml. of the sample to be tested and 5 ml. of sodium plumbite solution for about 15 sec. Add a small pinch of pure, dry flowers of sulfur, again shake for 15 sec. and allow to settle. The quantity of sulfur used should be such that practically all of it floats on the interface between the sample and the sodium plumbite solution.

Interpretation of Results.—If the sample is discolored, or if the yellow color of the sulfur film is noticeably masked, the test shall be reported as positive and the sample condemned as "sour." If the sample remains unchanged in color, and if the sulfur film is bright yellow or only slightly discolored with gray or flecked with black, the test shall be reported negative and the sample considered "sweet."

(*d*) *Sulfuric Acid Absorption Test:*

Apparatus.—One modified Babcock bottle with ground-glass stopper, graduated to 0.2 ml. as shown in Fig. 1; one 50-ml. graduated cylinder; and one 10-ml. pipette standardized to agree with the Babcock bottle.

The total height of the bottle including stopper shall be $7\frac{3}{4}$ to 8 in. (197 to 203 mm.). The bulb shall have an outside diameter of between $1\frac{3}{8}$ and $1\frac{29}{64}$ in. (35 and 37 mm.). The graduated portion of the neck shall have a length of $2\frac{1}{2}$ to 3 in. (63.5 to 76.2 mm.). The volume of the graduated portion shall be 10 ml. subdivided into fifty 0.2-ml. divisions, each fifth division line being longer than the others. The scale shall be numbered on the right in 10 per cent intervals beginning at zero, 10 ml. representing 100 per cent. The maximum error of the total graduation or any part thereof shall not exceed one-half the volume of the least graduation (1 per cent or 0.10 ml.). The 100 per cent mark shall be $1\frac{1}{16}$ to $1\frac{9}{16}$ in. (27 to 29 mm.) from the top of the neck. The neck shall be provided with an accurately ground glass stopper. The distance from the bottom of the stopper to the uppermost graduation shall be not less than 0.4 in. (10 mm.). The stopper and bottle shall bear a corresponding serial number.

Procedure.—Bring the temperature of the sample to 20 ± 1 C. Measure out 10 ml. of the sample into the clean dry modified Babcock bottle with the standard pipette and cool in ice water for 5 min. Add from a graduate 20 ml. of c.p. sulfuric acid (sp. gr. 1.83 to 1.84 at 20 C.; approximately 93.2 per cent). Pour the acid down the side of the bottle to prevent splashing. Again cool for 10 min. by allowing the bottle to stand in ice water, so that the water level is above the level of the sample in the bottle. Remove the Babcock bottle from the water bath, place the glass stopper previously wet with sulfuric acid in the bottle and shake violently for 1 min. Carefully add to the bottle sufficient sulfuric acid to bring the liquid level almost to the top graduation, and allow the stoppered bottle to stand over night (at least 12 hr. is necessary). Place the bottle in a water bath at 20 ± 1 C. for 15 min. Add sulfuric acid, previously brought to the temperature of 20 C., to bring the liquid level exactly to the top graduation. Read the scale at the lower surface of the solvent and report as percentage absorbed in sulfuric acid.

(*e*) *Flash Point.*—Standard Method of Test for Flash Point by Means of the Tag Closed Tester (A.S.T.M. Designation: D 56) of the American Society for Testing Materials.[4]

(*f*) *Distillation.*—Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.[5]

(*g*) *Acidity.*—This test shall be made immediately after recording the volume of residue in the distillation test. Transfer the cooled residue to a test tube, add three volumes of distilled water, and shake the tube thoroughly. Allow the mixture to separate and remove the aqueous layer to a clean test tube by means of a pipette. Add 1 drop of 0.1 per cent methyl orange solution. No pink or red color shall be formed.

Containers

5. Stoddard solvent shall be delivered in clean containers or tanks. If container previously has been used for other materials, such as fuel oil, etc., it shall be thoroughly cleaned and rinsed with Stoddard solvent.

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[4] 1936 Book of A.S.T.M. Standards, Part II, p. 907.

[5] 1938 Supplement to Book of A.S.T.M. Standards p. 137.

Tentative Method of Test for
ACID HEAT OF GASOLINE[1]

A.S.T.M. Designation: D 481 - 38 T

ISSUED, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method is suitable for determining the acid heat of aviation and motor gasolines having Reid vapor pressures[2] of 15 lb. or less. The method is roughly indicative of the amount of unsaturated hydrocarbons in the gasoline that are reactive with sulfuric acid under the conditions of this test.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Bottle.*—A high-grade vacuum bottle having a capacity of 450 to 470 ml. and a weight (glass bottle only) of 180 to 200 g. When 30 ml. of sulfuric acid (83.4 ± 0.1 per cent) is added to 150 ml. of distilled water and the mixture shaken for 3 min. following the procedure outlined in Section 5 (except that water is substituted for gasoline and 83.4 per cent sulfuric acid is substituted for 93 per cent sulfuric acid), the maximum temperature attained after shaking shall be 42 to 44 F. (23.3 to 24.4 C.) above the temperature prior to mixing. After the maximum temperature has been attained, the drop in temperature on standing for 15 min., due to thermal leakage, shall not exceed 1.5 F. (0.8 C.).

(*b*) *Closure.*—A two-holed rubber stopper, which shall fit snugly in the mouth of the bottle, and means shall be provided to hold the rubber stopper firmly in place. This may conveniently be done by cutting a 1-in. hole in the top of the metal screw cap to accommodate the thermometer and pressure-release tube. A metal washer, $\frac{1}{8}$ in. in thickness and having a hole 1 in. in diameter, shall be inserted between the stopper and the metal screw cap. These means for retaining the stopper are necessary as a safety precaution to prevent blowing out the stopper due to the pressure.

(*c*) *Thermometer.*—An A.S.T.M. acid-heat thermometer conforming to the following specifications which cover a 6-in. (152-mm.) immersion thermometer graduated in either Fahrenheit or Centigrade degrees, as specified, the ranges being 30 to 220 F. in 1 F. subdivisions or 0 to 105 C. in 0.5 C. subdivisions.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] Tentative Method of Test for Vapor Pressure of Petroleum Products (Reid Method) (D 323 - 38 T) of the American Society for Testing Materials, see p. 890.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISIONS: 0 to 105 C. in 0.5 C. or 30 to 220 F. in 1 F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter 6 to 7 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length 10 to 15 mm. Diameter 5 to 6 mm.

DISTANCE TO 0 C. or 32 F. LINE FROM BOTTOM OF BULB: 200 to 215 mm. (7.87 to 8.46 in.).

DISTANCE TO 105 C. or 220 F. LINE FROM TOP OF THERMOMETER: 25 to 40 mm. (0.98 to 1.57 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATIONS: All lines and figures clear cut and distinct. The whole-degree Centigrade lines or the first and each succeeding 5 F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 5 C. or 10 F.

IMMERSION: 6 in. (152 mm.). The words "152-mm. immersion" on Centigrade, or "6-in. immersion" on Fahrenheit, thermometer to be etched on the thermometer and a line shall be etched on the thermometer 152 mm. or 6 in. from end of bulb.

SPECIAL MARKING: "A.S.T.M. Acid Heat," a serial number and the manufacturer's name or trade-mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.5 C. or 1 F., respectively.

STANDARDIZATION: The thermometer shall be standardized at the ice point and at intervals approximately 30 C. or 50 F. for 152-mm., or 6-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
20 C.	70 F.	20 C.	70 F.
40 C.	100 F.	31 C.	86 F.
70 C.	150 F.	40 C.	104 F.
100 C.	212 F.	48 C.	118 F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Acid Heat, 0 to 105 C.", or "A.S.T.M. Acid Heat, 30 to 220 F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications, the following descriptions of terms apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

(*d*) *Glass Stopcock.*—A glass tube of approximately 5 mm. in outside diameter carrying a glass stopcock, provided as a means of releasing the pressure.

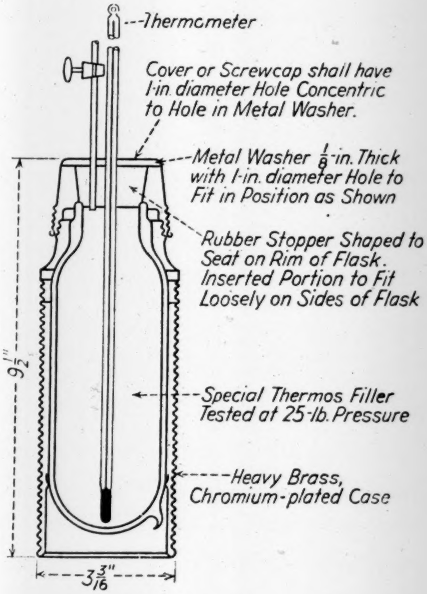
Thermometer
Cover or Screwcap shall have 1-in. diameter Hole Concentric to Hole in Metal Washer.
Metal Washer $\frac{1}{8}$-in. Thick with 1-in. diameter Hole to Fit in Position as Shown
Rubber Stopper Shaped to Seat on Rim of Flask. Inserted Portion to Fit Loosely on Sides of Flask
$9\frac{1}{2}''$
Special Thermos Filler Tested at 25-lb. Pressure
Heavy Brass, Chromium-plated Case
$3\frac{3}{16}''$

FIG. 1.—Apparatus for Acid Heat Test of Gasoline.

(*e*) *Assembly.*—A suitable assembly for the acid-heat determination is shown in Fig. 1. The assembly should be tested with air at 25-lb. pressure to make sure it will not break or that the stopper will not be blown out under the pressure developed during the test. Frequent inspection should be made of the threads on the retaining cap to insure that they are not worn to an extent likely to permit release of the cap during performance of the test.

Reagent

3. Sulfuric acid having a strength of 93 ± 0.1 per cent H_2SO_4 shall be used in this test.

Test Sample

4. In the case of gasolines having acid heats of 50 F. (28 C.) or less, a 150-ml. sample shall be used for the test. In the case of gasolines having acid heats over 50 F. (28 C.) there shall be used for the test a mixture consisting of 75 ml. of gasoline and 75 ml. of Stoddard solvent or kerosine having an acid heat of less than 5 F. In the case of gasolines having acid heats over 100 F. (56 C.), a mixture of 50 ml. of gasoline and 100 ml. of Stoddard solvent or kerosine shall be used.

Procedure

5. (*a*) A 150-ml. sample (Section 4) shall be measured into the clean and dry vacuum bottle, both sample and bottle to be at a temperature of 60 to 80 F. (15.5 to 26.5 C.), and after 2 min. the temperature of the gasoline in the vacuum bottle shall be measured and recorded. As a safety precaution in testing any gasoline whose acid heat is not known approximately, it is recommended that a preliminary test be made with a one-to-two dilution of the sample as described in the last sentence of Section 4.

(*b*) Exactly 30 ml. of sulfuric acid at the same temperature, (plus or minus 0.5 F. (0.3 C.)) as that recorded for the gasoline shall be poured into the vacuum bottle, and the two-holed rubber stopper bearing the pressure-release stopcock and thermometer shall be inserted. The metal retaining cap shall then be tightly screwed down to hold the stopper assembly in place. The thermometer shall be placed in the stopper so that its bulb will be covered by the acid layer and the bottom of the bulb will be from 1 to 2 mm. from the bottom center of the vacuum bottle when the retaining cap is screwed down.

(*c*) The pressure-release stopcock shall be closed and the assembly wrapped in a towel as a safety precaution in case of breakage. The bottle and contents shall be shaken for 3 min. with an up-and-down motion such that the liquid is thrown to the top of the bottle. The rate of shaking shall be 130 to 160 up-and-down motions per minute. Sixty seconds shall elapse between the time of beginning the acid addition and the time of beginning the shaking.

(*d*) After completing the shaking, the temperature indicated by the thermometer after 10 min. have elapsed from the end of the shaking period shall be recorded. At the end of the test, the pressure shall be carefully released by opening the glass stopcock before loosening the metal cap.

(*e*) The difference between the initial and final temperatures shall be recorded as the acid heat of the gasoline. When the sample tested is a mixture of 75 ml. of gasoline and 75 ml. of Stoddard solvent or kerosine the result obtained shall be multiplied by 2 and reported as "Acid Heat (1:1) - - - - - - - deg. Fahr." When the sample tested is a mixture of 50 ml. of gasoline and 100 ml. of Stoddard solvent or kerosine the result obtained shall be multiplied by 3 and reported as "Acid Heat (1:2) - - - - - - deg. Fahr."

Reproducibility of Results

6. Determinations by different operators in different laboratories should check within 10 per cent.

Tentative Method of Test for

ASH CONTENT OF PETROLEUM OILS[1]

A.S.T.M. Designation: D 482 - 38 T

ISSUED, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for use in the determination of the ash content of fuel oils and other petroleum oils.

Procedure

2. A platinum, porcelain, silica dish, or wide-form crucible (Note 1) of 50 to 100-ml. capacity shall be heated to redness and weighed after cooling. An approximately 20-g. sample of the oil (Note 2) shall be placed in the dish and weighed to the nearest 0.1 g. The dish shall be heated gently by means of a bunsen burner until the oil can be ignited at the surface (Note 3). The burner shall then be removed and the oil allowed to burn completely. All free carbon on the sides of the dish shall be completely burned and the residue heated with a strong flame, or in a muffle furnace, until all carbonaceous matter has disappeared. After cooling, the dish shall be weighed. The heating shall then be repeated until a constant weight is obtained. The weighing and handling of the dish shall be in accordance with accepted quantitative technique.

NOTE 1: *Caution.*—Use of a platinum dish should be avoided if the sample contains lead, zinc, or other metals which attack platinum at high temperatures.

NOTE 2.—This size sample is suitable for ash contents in the range of 0.02 to 0.2 per cent; but in the case of lower or higher ash contents, a larger or smaller sample may be used. In such cases the result shall be specified or reported as follows: "Ash (............g. sample)............per cent."

NOTE 3.—To avoid foaming and loss of sample in the case of samples containing moisture, it is advisable to add 1 to 2 ml. of absolute alcohol before heating.

Reporting Results

3. The weight of the residue expressed as a percentage of the original sample shall be reported as the percentage ash content.

Reproducibility of Results

4. Duplicate determinations by the same operator, or the average results obtained by two different operators, should agree within 10 per cent.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

Tentative Method of Test for
CONSISTENCY OF LUBRICATING GREASES AND PETROLATUM[1]

A.S.T.M. Designation: D 217 – 38 T

Issued, 1925; Revised, 1926, 1927, 1933, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Interpretation of Results—The unworked (original) consistency of lubricating greases is determined by a number of factors which are very difficult to control. The soap content is the most important factor, but the kind of fats used, the method of manufacture, the final water content, the rate of cooling, and the temperature of filling shipping containers are all important in determining the final consistency. Thus it is impracticable to maintain the consistency within narrow limits. Any working or remelting of a grease after it is in the container will change the consistency. The consistency changes also on standing, most rapidly during the first 48 hr. after manufacture.

Although many tests are based on the unworked consistency, this property bears no definite relationship to the worked consistency which is the value of practical importance for most uses of lubricating greases. Final tests should therefore be made as described in Section 8 for determining worked consistency.

On the other hand, for very hard greases, such as railroad greases, the unworked consistency is generally the property of practical importance and they should be so tested.

Scope

1. This method of test is intended for use in measuring with a penetrometer the unworked or the worked consistency of lubricating greases which have a worked consistency less than 400, and in measuring the original consistency of petrolatum.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Penetrometer.*—A suitable penetrometer, with special cone, which permits the cone to drop without appreciable friction and which indicates accurately the depth of penetration. A simplified sketch of such a penetrometer with cone attached is shown in Fig. 2. The scale of the penetrometer shall be calibrated in tenths of a millimeter.

(*b*) *Cone.*—A cone, constructed of stainless steel or brass, with a detachable hardened-steel or stainless-steel tip. It shall conform to the dimensions shown in Fig. 1 except that the interior construction may be modified as desired. The outside surface of the cone and tip shall be given a very smooth finish. The total moving weight of the cone and attachments shall be 150 g.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

(c) *Grease Worker.*—A worker, as shown in Fig. 3, to be used when the worked consistency of lubricating grease is to be measured.

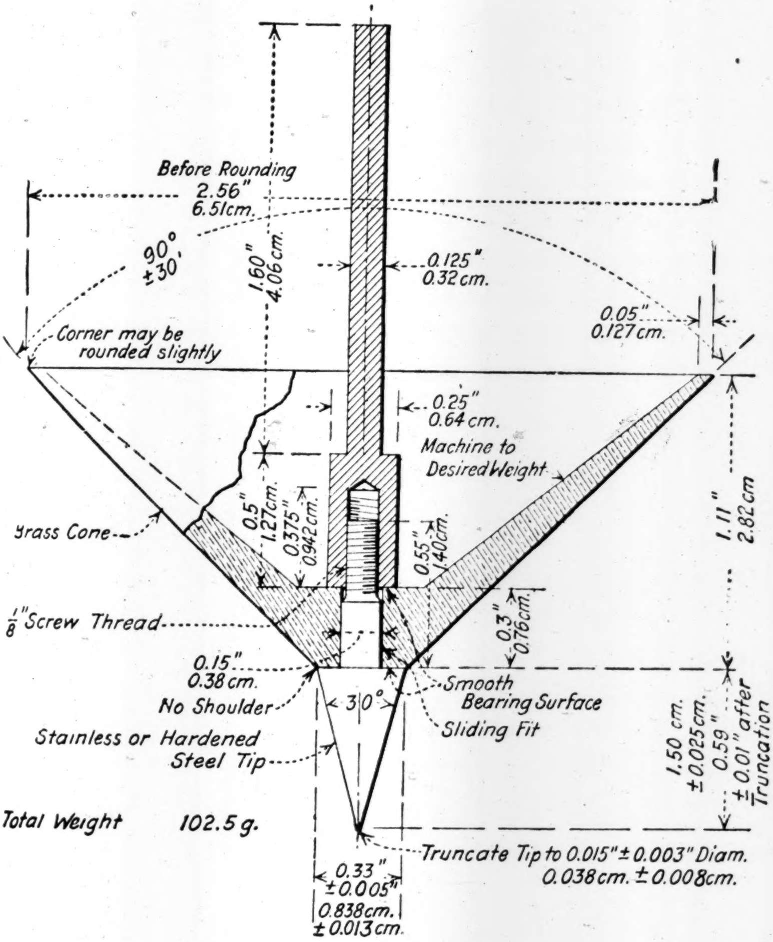
Before Rounding
2.56"
6.51cm.
90°
±30'
1.60"
4.06 cm.
0.125"
0.32 cm.
0.05"
0.127 cm.
Corner may be rounded slightly
0.25"
0.64 cm.
Machine to Desired Weight
Brass Cone
0.5"
1.27 cm.
0.375"
0.942 cm.
0.55"
1.40 cm.
1.11"
2.82 cm
1/8" Screw Thread
0.3"
0.76 cm.
0.15"
0.38 cm.
No Shoulder
30°
Smooth Bearing Surface
Sliding Fit
Stainless or Hardened Steel Tip
1.50 cm.
±0.025 cm.
0.59"
±0.01" after Truncation
Total Weight 102.5 g.
Truncate Tip to 0.015" ± 0.003" Diam.
0.038 cm. ± 0.008 cm.
0.33"
±0.005"
0.838 cm.
±0.013 cm.

FIG. 1.—Penetrometer Cone.

(d) *Constant-Temperature Bath.*—A constant-temperature bath regulated to 77 ± 1 F. (25 ± 0.5 C.) is desirable to bring the samples to the temperature of test, if many tests are to be made.

Samples for Tests

3. (a) *Lubricating Grease.*—Tests for the unworked consistency of a lubricating grease shall be made only on a sample in the original container (or on a cake or slab in the case of very hard greases). Cans having a capacity of 1 lb., approximately 8 cm. in diameter, are the best containers for this purpose. The penetration of soft lubricating greases will vary with the diameter of the container. If samples are taken

from large containers, more or less working is involved, consequently, the test shall be made only on a sample worked as specified in Section 8. Samples of discolored or rancid grease shall be rejected.

(*b*) *Petrolatum.*—All samples of petrolatum shall be tested for original consistency after melting and cooling to the temperature of the test.

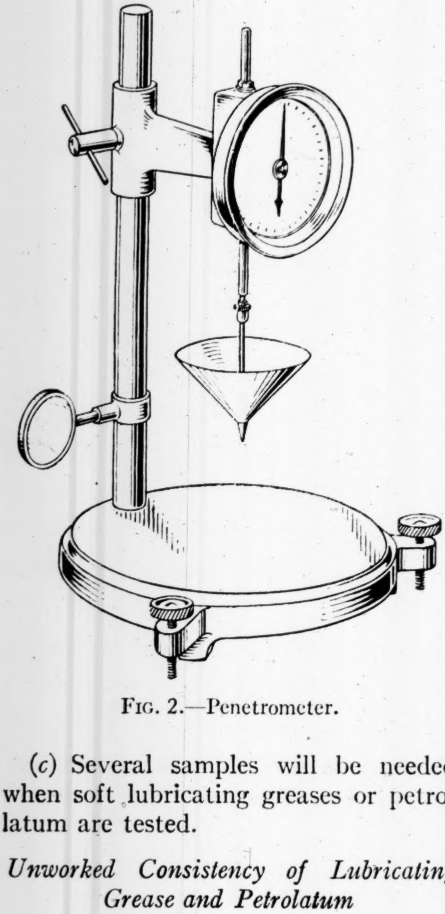

FIG. 2.—Penetrometer.

(*c*) Several samples will be needed when soft lubricating greases or petrolatum are tested.

Unworked Consistency of Lubricating Grease and Petrolatum

Bringing to Temperature of Test

4. The temperature of the sample shall be brought to 77 ± 1 F. (25 ± 0.5 C.) before the test. If the sample is initially within 3 to 4 F. (1.5 to 2 C.) of this temperature, it may be brought to 77 F. (25 C.) by placing in a water bath for 30 or 40 min.; but if the initial temperature is outside this range, it shall be placed in the constant-temperature bath for 1½ hr. to obtain the desired constant temperature. If the room temperature is more than 3 to 4 F. (1.5 to 2 C.) from 77 F. (25 C.) a lid shall be placed on the can, sealing throughout with grease or petrolatum to prevent the entrance of water, and the can immersed in the bath for the required period. Otherwise, the temperature of the surface will be different from that of the main body of the lubricating grease or petrolatum.

Procedure

5. (*a*) The surface of the sample of lubricating grease or petrolatum shall be cut level and very smooth with a knife. Care shall be taken not to work the surface.

(*b*) The can of lubricating grease or petrolatum shall be placed on the penetrometer table and the cone lowered until the tip just touches the top surface of the sample. Watching the shadow of the tip is an aid to accurate setting. When testing soft lubricating greases (unworked consistency of 310 or more), it is very important that the cone tip shall be placed as exactly as possible at the center of the lubricating grease container. With older penetrometers it is then necessary to set the scale at zero but with new apparatus the scale and cone move as a unit and no setting is needed. Finally, the plunger shall be quickly released and held free for 5 sec. The total penetration shall be read from the scale and reported as the unworked consistency.

Spacing of Tests in Cans

6. The total surface area disturbed by the test will have a diameter about

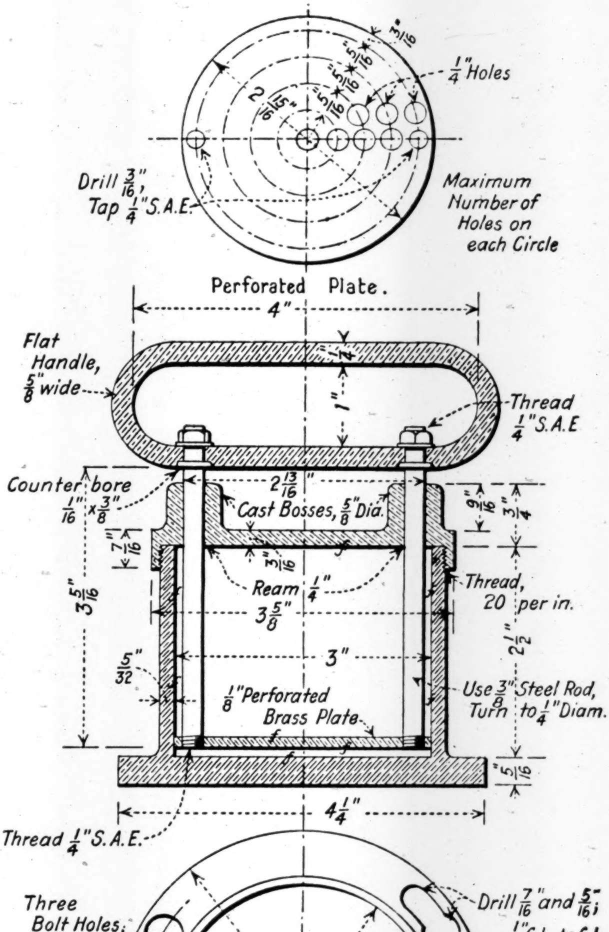
1/4" Holes
3/16"
5/16"
5/16"
5/16"
2 15/16"
Drill 3/16", Tap 1/4" S.A.E.
Maximum Number of Holes on each Circle
Perforated Plate.
4"
Flat Handle, 5/8" wide
1/4"
1"
Thread 1/4" S.A.E
Counter bore 1/16" × 3/8"
2 13/16"
Cast Bosses, 5/8" Dia.
9/16"
3/4"
7/16"
3/16"
Ream 1/4"
Thread, 20 per in.
3 5/16"
3 5/8"
2 1/2"
3"
5/32"
1/8" Perforated Brass Plate
Use 3/8" Steel Rod, Turn to 1/4" Diam.
f
5/16"
4 1/4"
Thread 1/4" S.A.E.
Three Bolt Holes; Equal Spacing
Drill 7/16" and 5/16"; 1/2" C.L. to C.L.
4 1/4"
3 5/16"
1 7/8" Rad.
3"
All Fillets 1/8" Diameter
Material: Brass, except Rods
Plan of Base.

FIG. 3.—Grease Worker.

equal to the measured depth of penetration. In order to prevent one test from being affected by the disturbed area of a previous test or by sides of the can, the tip shall never be placed nearer the sides of the can or the edge of a previous hole than the penetration distance of that particular lubricating grease or petrolatum. The lubricating grease or petrolatum shall not be smoothed over for further tests.

Number of Tests Required

7. Five tests shall be made and the average reported as the unworked consistency if the mean deviation of these readings does not exceed 3.0 per cent. If the mean deviation exceeds 3.0 per cent, the average of ten readings shall be reported.

Worked Consistency of Lubricating Grease

Procedure

8. The procedure for determining the consistency of worked lubricating greases (Note 1) shall be the same as that for unworked consistency except that the sample to be tested shall be transferred to the worker, which shall be filled heaping full with a minimum inclusion of air, brought to 75 ± 2 F. (24 ± 1 C.) and worked with 60 full double strokes of the plunger (Note 2). The top and plunger shall then be removed (Note 3) and the temperature adjusted to 77 ± 1 F. (25 ± 0.5 C.). Then the surface shall be smoothed and the test made as described in Section 5 (*b*). As soon as one test is finished, the surface may be smoothed over for the next, taking care to avoid creating air pockets.

Note 1.—Due to the rapid change in consistency of cold-set lubricating greases after working it is not advisable to determine their worked consistency.

Note 2.—In working stiff greases a wall bracket for holding the worker is helpful. Metal strips open on the inside are welded on three sides of a steel plate 6 by 6 in. or larger. The plate is securely fastened to the wall at the desired height and the base of the worker dropped in behind the metal strips to hold it firmly in position.

Note 3.—Bouncing the worker a few times on a table is very helpful in removing occluded air from soft lubricating greases.

Number of Tests Required

9. The number of tests required shall conform to the requirements prescribed in Section 7.

APPROVED AS
AMERICAN TENTATIVE STANDARD
BY THE AMERICAN STANDARDS ASSOCIATION
A.S.A. No.: Z11.37-1938

Tentative Method of Test for
KNOCK CHARACTERISTICS OF MOTOR FUELS[1]

A.S.T.M. Designation: D 357 - 38 T

Issued, 1933; Revised, 1934, 1936, 1937, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for determining the knock characteristics, in terms of an arbitrary scale of octane numbers, of gasolines and equivalent fuels for use in spark-ignition engines other than engines for aircraft. It is applicable only at atmospheric pressures not less than 28.5 in. (724 mm.) of mercury.

A.S.T.M. Octane Number

2. The A.S.T.M. octane number of a motor fuel is the whole number nearest to the octane number (Note 1) of that mixture of *iso*octane with normal heptane which the motor fuel matches in knock characteristics when compared by the procedure specified herein.

Note 1.—Octane number is defined by and is numerically equal to the percentage by volume of *iso*octane (2,2,4-trimethylpentane) in a mixture of *iso*octane and normal heptane, used as a primary standard for measurement of knock characteristics. Thus, by definition, normal heptane has an octane number of zero and *iso*octane of 100.

Apparatus

Apparatus

3. The knock-testing unit described in this section shall be used without modification. The engine shall be known as the "C.F.R. Engine" and shall be marked[2] by plate or other approved means with a combination of the respective emblems of the American Society for Testing Materials and the Cooperative Fuel Research Committee, thus:

The apparatus shall consist of a continuously-variable-compression engine together with suitable loading and accessory equipment, mounted on a base plate. All necessary instruments and acressories are furnished with the unit. Important specifications are as follows:

(*a*) *Engine.* — Continuously-variable-compression, one-cylinder, with dimensions as follows:

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

This method heretofore known as the C.F.R. Motor Method is based on the apparatus and procedure developed by the Cooperative Fuel Research Committee, composed of representatives of the American Petroleum Institute, Automobile Manufacturers Association, Society of Automotive Engineers, Inc., and National Bureau of Standards.

[2] At present the sole authorized manufacturer of the C.F.R. Engine is the Waukesha Motor Co., Waukesha, Wis. Other manufacturers may be approved in the future, but testing laboratories should not purchase knock-testing units except from the Waukesha Motor Co. without ascertaining whether such units have been approved. Inquiries in this connection should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 50 W. Fiftieth St., New York, N. Y.

Compression-ratio scale	4 to 10
Bore, in	3.25
Stroke, in	4.50
Displacement, cu. in	37.4
Valve-port diameter, in	1.187
Connecting-rod bearing:	
diameter, in	2.25
length, in	1.625
Front main bearing:	
diameter, in	2.25
length, in	2.00
Rear main bearing:	
diameter, in	2.25
length, in	4.25
Piston pin, floating, diameter, in	1.25
Connecting rod, center to center, in.	10.00
Timing-gear face, in	1.00
Piston rings, number	5
Exhaust pipe, diameter, in	1.25
Spark plug, size, mm	18
Weight of engine, lb. (approximate).	475
Weight of complete unit, lb. (approximate)	1375

(*b*) *Crankshaft.*—Fully machined, heat-treated, and counter-balanced.

(*c*) *Crankcase.*—Cast iron, with rigid end walls.

(*d*) *Connecting Rod.*—Rifle-drilled, S.A.E. No. 1045 steel, heat-treated, bearing alloy cast directly into big end.

(*e*) *Main Bearings.*—Renewable sleeve bushings, babbitt-lined.

(*f*) *Valves.*—Silcrome. Inlet valve with specially designed shroud. Stellited valves and valve-seat inserts optional.

(*g*) *Valve Timing.*—The checking clearance on both valves shall be 0.010 in. (for running clearance, see Section 6(*l*)). Intake valve opens 10 deg. a.t.d.c., closes 34 deg. a.b.d.c. Exhaust valve opens 40 deg. b.t.d.c., closes 15 deg. a.t.d.c.

(*h*) *Push Rods.*—Mushroom type with lock-nut adjustment.

(*i*) *Cylinder.*—One piece integral with head, cast-iron alloy, bored and honed, Brinell hardness 220 ± 20.

(*j*) *Cooling System.*—Evaporative.

(*k*) *Lubrication.*—Pressure feed to main, connecting-rod, piston-pin and camshaft bearings, and to idler-gear stud and gears.

(*l*) *Oil Heater and Thermometer.*—Electric heater in base to bring oil to operating temperature quickly, and a thermometer on the instrument panel to indicate when equilibrium temperature has been reached.

(*m*) *Ignition.*—Either a coil system or a magneto. A neon-tube spark indicator is built into the engine. Spark advance is automatically adjusted as the compression ratio is changed.

(*n*) *Spark Plug.*—Conforming to the standard metric plug having the tolerances and thermal characteristics equal to the No. 8 (A-64-S) spark plug furnished by the Champion Spark Plug Co., Toledo, Ohio.

(*o*) *Carburetor.*[3]—A special C.F.R. multiple-bowl carburetor with fuel containers is furnished. It has a metering jet for each float bowl, a horizontal atomizing jet in the air stream and a venturi with minimum internal throat diameter of 0.563 ± 0.001 in. Each float bowl is individually adjustable for fuel level for varying mixture ratio, the fuel level for a given air-fuel ratio being dependent upon the size of the metering jet. The carburetor intake is fitted with an elbow and an intake silencer mounted vertically.

(*p*) *Throttle Plate.*—A throttle plate is furnished, which shall be installed between the carburetor and the intake manifold, with a standard copper-asbestos gasket between the plate and the carburetor; and a standard copper-asbestos gasket, a polished stainless steel heat shield with plate downward, and a special copper-asbestos heat-insulating gasket 0.375 in. in thickness between the plate and the manifold. This throttle plate shall have a centrally located vertical slot with semicircular ends, 1.312 ± 0.005 in. in length and 0.250 ± 0.005 in. in width.

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[3] The use of knock-testing apparatus equipped with the carburetor described in the 1933 edition of the method (*Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 746 (1933); also 1933 Book of A.S.T.M. Tentative Standards, p. 540) is no longer permissible for referee testing

(*q*) *Mixture-Heater Assembly.*—As supplied by the manufacturer, consisting of (*1*) a manifold, (*2*) an electric immersion heater, rheostat and automatic safety switch, and (*3*) a special mercury thermometer of suitable range. The heater element shall be installed so that (*a*) the opening between the two prongs is directly opposite the carburetor inlet, (*b*) the prongs are straight and parallel to each other, centrally located with respect to the manifold walls, and (*c*) the lower ends of the prongs are 0.125 to 0.250 in. below the horizontal plane through the center of the manifold outlet. The thermometer shall be vertical and located so that the center of the bulb is at the center of the manifold, 1.875 ± 0.010 in. from the center axis of the vertical section of the manifold and 0.375 ± 0.010 in. from the flush face of the flange of the manifold outlet.

(*r*) *Instruments.*—Knock intensity is measured by means of a bouncing pin, in conjunction with a knockmeter. The adjustable-leaf bouncing pin is the preferred type.[4] It consists of a cylindrical steel pin 0.218 ± 0.001 in. in diameter, to the upper end of which is fitted a fiber tip, the combined length of pin and tip being 7.000 ± 0.015 in. The pin is maintained in a vertical position on the engine by two bushings in a hollow barrel. The bottom end rests on a hardened spring-steel diaphragm, 0.543 ± 0.003 in. in diameter and 0.015 ± 0.0005 in. in thickness, which is locked in the end of the barrel with a hollow nut. Attached to the head of the barrel and suitably insulated are two flat leaf springs with contact points immediately above the bouncing pin. These springs should be 0.021 ± 0.0005 in. in thickness. Adjusting screws are provided for adjustment of the spring tensions and gap clearance. The knockmeter is a device for integrating the current which flows in the bouncing-pin circuit when the contacts are closed by the upward movement of the bouncing pin that results from knock. Current is supplied from a small direct-current generator, belt-driven from the power-absorbing unit. This current flows through a resistance heating element located near a thermocouple. The potential produced at the thermocouple junction when current flows through the heating element actuates the knockmeter and produces a continuous indication of knock intensity.

(*s*) *Power-Absorbing Unit.*—The engine is connected by V-type belts to an electric generator which preferably should be an induction motor with synchronous characteristics but may be any electric generator capable of maintaining proper operating conditions. In most cases the electric generator will act as a starting motor to crank the engine, but if a direct-current generator is used and no outside source of current is available, the engine may have to be cranked by hand.

(*t*) *Exhaust Pipe.*—A separate exhaust pipe shall be used for each engine. It shall be made of pipe of not less than 1¼ in. in inside diameter having a maximum of two ells and a total length not to exceed 20 ft. The use of a short straight-through muffler with passage 1¼ in. in diameter is permissible.

Foundation

4. The foundation shall be of concrete, at least 15 in. in height above the floor level, resting, if possible, directly on the ground. Otherwise, special provision must be made to eliminate vibrations that may influence ratings and the

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[4] The use of the bouncing pin described in the 1933 edition of the method (*Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 746 (1933); also 1933 Book of A.S.T.M. Tentative Standards, p. 540) is permissible.

manufacturer should be consulted. For convenience in operation, the foundation should be located at least 2 ft. from any wall. Dimensions are furnished with the apparatus.

Reference Fuels

5. (*a*) *Primary Reference Fuels.*—The primary reference fuels shall be *iso*octane (2, 2,4-trimethylpentane), and normal heptane. Only primary reference fuels certified by the National Bureau of Standards, and supplied by manufacturers designated by the A.S.T.M. shall be used.[5]

(*b*) *Secondary Reference Fuels.*—To insure a greater degree of reproducibility in testing, it is preferable to use secondary[6] reference fuels which have been calibrated against the primary reference fuels on a large number of engines. Such secondary reference fuels may be straight-run or other stable gasolines suitable for the purpose. The calibration shall be expressed in terms of the octane-number scale, shall be based on results by this method from at least ten laboratories, and shall be certified by the National Bureau of Standards (Note 2).

Note 2.—For the present this certification is based on tests made by members of the Motor Fuels Division of the C.F.R. Committee on samples from each batch of secondary reference fuels, and on blends of such secondary fuels against blends of *iso*octane and normal heptane. A certificate is then issued to the producers authorizing them to guarantee to the purchasers that the material shipped as a part of a batch so tested, and to quote the results of the tests.

Standard Operating Conditions

6. The engine shall be run under the following standard conditions:

(*a*) *Engine Speed.*—Constant, 900 ± 9 r.p.m.

(*b*) *Jacket Temperature.*—Constant within plus or minus 1 F. (0.6 C.) and at a temperature between the limits of 209 and 215 F. (98 and 102 C.).

Note 3.—For routine testing at barometric pressures lower than 28.5 in. of mercury an ethylene-glycol solution may be used to maintain standard jacket temperature. This is not permitted in referee testing.

(*c*) *Spark Advance.*—Automatically controlled:

26.0 deg. at 5:1 compression ratio (basic setting),
24.0 deg. at 5.5:1 compression ratio,
22.0 deg. at 6:1 compression ratio, and
19.0 deg. at 7:1 compression ratio.

(*d*) *Mixture Temperature.*—The mixture temperature shall be maintained at 300 ± 2 F. (149 ± 1.1 C.) as indicated by the mercury thermometer.

(*e*) *Carburetor Adjustment.*—The carburetor shall be adjusted for maximum knock. The fuel-level reading for maximum knock shall be between 0.8 and 1.8 in. To meet this requirement in the case of some fuels it may be necessary to change the size of the carburetor jet.

(*f*) *Bouncing-Pin Assembly.*—The gap setting shall be between 0.002 and 0.005 in. (Note 4). The sensitivity shall not be less than four scale divisions of the knockmeter per octane number and the fluctuation in knockmeter divisions while readings are being made, shall not exceed 20 per cent of the sensitivity.

Note 4.—A correct setting shall give a 55 to 60 knockmeter reading for a blend of 65 per cent *iso*octane and 35 per cent normal heptane under standard conditions (see Section 8). When fuels above 82 A.S.T.M. octane number

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[5] At present (June, 1938), certification is based on the specifications shown in the Appendix and the designated manufacturers are:

*Iso*octane	Röhm & Haas Co., 222 W. Washington Square, Philadelphia, Pa.
Normal heptane	California Chemical Co., 405 Lexington Ave., New York, N. Y., or Newark, Calif.

[6] Such secondary reference fuels are obtainable from the Standard Oil Development Co., Elizabeth, N. J., with calibration curves as determined in accordance with this method, giving octane numbers for these fuels blended with each other.

are being tested, the correct setting shall also result in the same reading for a 90-octane blend at 7.1 ± 0.2 to 1 compression ratio corrected for barometric pressure (see Section 10 (*b*)).

(*g*) *Standard Knock Intensity.*—Standard knock intensity shall be that obtained with a blend by volume of 65 per cent *iso*octane and 35 per cent normal heptane under the standard operating conditions of this method at a compression ratio of 5.3 to 1 and a barometric pressure of 29.92 in. (760 mm.) of mercury (see Section 8).

(*h*) *Clearance Volume.*—The clearance volume measured to the top face of the bouncing-pin hole shall be 140 ± 0.5 ml. with the engine at top dead center and with a 5.5 to 1 compression ratio (Note 5). At this volume the micrometer should be set to read 0.500 in.

NOTE 5.—Rebored cylinders shall not be used for referee testing. When rebored cylinders are used for routine testing this clearance volume becomes:

140.8 ± 0.5 ml. for 0.01 in. oversize,
141.6 ± 0.5 ml. for 0.02 in oversize, and
142.5 ± 0.5 ml. for 0.03 in. oversize.

(*i*) *Compression Pressure.*—At a compression ratio of 5.3 to 1 corrected for barometric pressure (see Section 8), the compression pressure shall be 114 ± 2 psi. absolute (99 ± 2 lb. gage) and at a compression ratio of 7.1 to 1 corrected for barometric pressure (see Section 10 (*b*)), 162 ± 3 psi. absolute (147 ± 3 lb. gage). Compression pressures outside these limits may be due to inaccuracy of the pressure gage. The check valve on the gage must be kept lubricated with an oil of Saybolt Universal viscosity of 50 to 100 sec. at 100 F. (37.8 C.).

(*j*) *Breaker-Point Clearance.*— 0.020 in.

(*k*) *Spark Plug.*—Gap setting, 0.025 in.

(*l*) *Valve Clearances, Cold.*—Intake 0.008 in., exhaust 0.010 in.

(*m*) *Crankcase Lubricating Oil.*—S.A.E. 30 (Note 6).

NOTE 6.—The viscosity range of crankcase lubricating oil, S.A.E. 30, is from 185 to 255 sec. when determined on the Saybolt Universal viscosimeter at 130 F. (54.4 C.), in accordance with the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88) of the American Society for Testing Materials.[7]

(*n*) *Oil Pressure.*—25 to 30 psi. under operating conditions.

(*o*) *Oil Temperature.*—The electric oil heater shall be used only to raise the oil temperature rapidly to the equilibrium operating temperature, 120 to 150 F. (49 to 65 C.), normal operation maintaining the equilibrium thereafter. By "equilibrium" is meant that steady temperature attained by the oil upon continuous operation of the engine without the use of the heater.

(*p*) *Cooling Liquid.*—Distilled water or rain water.

PROCEDURE

Starting and Stopping the Engine

7. While the engine is being turned over by electric motor the ignition shall be turned on and the carburetor set so as to draw fuel from one float bowl. To stop the engine the fuel and ignition shall be turned off and then the electric motor stopped. To avoid corrosion of valves and seats between operating periods the engine shall be turned over by hand until both valves are closed.

Standard Knock Intensity

8. With the engine temperature in equilibrium the proper knock intensity for determining octane numbers shall be that obtained with a blend by volume of 65 parts of *iso*octane and 35 parts of normal heptane (Note 7) at a compression ratio of 5.30 to 1 when testing at a

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[7] 1938 Supplement to Book of A.S.T.M. Standards, p. 148.

barometric pressure of 29.92 in. (760 mm.) of mercury and with the carburetor set for maximum knock. For other barometric pressures not less than 28.5 in. (724 mm.) (Note 8) the compression ratio shall be that obtained from the following formula:

$$\text{C. R.} = 5.30 + (29.92 - B)\,0.16$$

where:

C.R. = the compression ratio, and

B = the barometric pressure in inches of mercury measured by a brass scale, corrected to a temperature of 28.5 F. (−1.95 C.).[8]

Note 7.—A blend of certified secondary reference fuels equivalent to a blend of 65 parts of *iso*octane and 35 parts of normal heptane may be used.

Note 8.—For routine testing at barometric pressures less than 28.5 in., standard compression pressure may be approximated by appropriately increasing the effective intake pressure. This may be done by removing the throttle plate and enlarging the venturi or by supercharging. The compression ratio for standard knock intensity shall be that defined above, substituting "effective intake pressure" for "barometric pressure" in the equation. This is not permissible in referee testing.

Adjusting of Bouncing Pin

9. For inspection and preliminary adjustment in accordance with the manufacturer's instructions[9] the bouncing pin shall be removed from the engine. Inspection shall be made to see that the contact points are smooth, that all connections are tight, and that the diaphragm is gas-tight (a test under 200 psi. gage is sufficient). After preliminary adjustment of the spring tensions and gap of the bouncing-pin assembly, the pin shall be replaced in the engine for final adjustment. With the engine operating at standard knock intensity and with the prescribed bouncing-pin gap and sensitivity, the knockmeter reading shall be 55 to 60. To accomplish this, it may be necessary to alter the gap and spring tensions slightly.

Check of Test Conditions

10. (*a*) Engine and test conditions shall not be regarded as correct unless a blend of 68 per cent of one-degree benzene and 32 per cent of normal heptane matches a blend by volume of 65 ± 0.3 per cent *iso*octane and 35 ± 0.3 per cent normal heptane under the procedure specified in this method. If this match cannot be obtained under standard conditions by adjustment of the bouncing pin, the mechanical condition of the engine shall be checked.

Note 9.—For routine checking purposes, a 65-octane blend of one-degree benzene and certified secondary reference fuels may be used.

Note 10.—"One-degree" benzene[10] is a commercial product conforming to the following requirements:

(*a*) Boiling range not greater than 1 C., embracing the boiling point of chemically pure benzene.

(*b*) Specific gravity of from 0.882 to 0.886, when determined in accordance with the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287) of the American Society for Testing Materials.[11]

(*c*) Free from hydrogen sulfide, carbon disulfide and thiophene.

(*d*) Free from turbidity, with color not darker than a solution of 3 mg. of potassium dichromate in 1 liter of water when compared in 50-ml. Nessler tubes.

(*b*) To make certain that engine and testing conditions are correct throughout the testing range a check shall be made with a 90-octane reference fuel. The standard knockmeter reading (55 to 60) should be obtained at 7.1 ± 0.2 to 1 compression ratio corrected for barometric pressure in accordance with the following formula:

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[8] $B = B' - 0.00009\,B'\,(t' - 28.5)$

where B' = the observed barometric pressure, and

t' = the observed temperature of the barometer in deg. Fahr.

[9] See "A.S.T.M.-C.F.R. Knock-Testing Unit—Care and Operation," available from the Waukesha Motor Co., Waukesha, Wis.

[10] "One-degree" benzene may be procured from the Barrett Co., 40 Rector St., New York City.

[11] 1937 Supplement to Book of A.S.T.M. Standards, p. 121

$$C.R. = 7.1 + (29.92 - B)\ 0.21$$

where:

C.R. = the compression ratio, and

B = the barometric pressure in inches of mercury measured by a brass scale, corrected to a temperature of 28.5 F. (– 1.95 C.).[8]

(*c*) For subsequent tests on fuel samples the compression ratio shall be set to duplicate the knock intensity as recorded in Paragraph (*b*) using the knockmeter as a guide, provided no change has been made in the bouncing-pin adjustment in the meantime. In no case shall tests be made if the engine does not cease firing when ignition is interrupted.

Outline of Test

11. The octane number of a fuel shall be ascertained by comparing the knock intensity for the fuel with those for various blends of the reference fuels until two blends differing in knock rating by not more than two octane numbers are found, one of which gives a higher knock intensity than the fuel and the other a lower knock intensity. The knock intensity shall be measured by the bouncing-pin indicator in conjunction with the knockmeter. Before the test sample and the blends of the reference fuels can be compared, the compression ratio shall be set to give the proper knock intensity for the test sample with the carburetor adjusted to give maximum knock.

Adjustment of Compression Ratio and Carburetor

12. (*a*) Using the fuel, the rating of which is to be determined, the compression ratio and carburetor shall be adjusted as follows: After one bowl of the carburetor has been filled with the fuel sample the compression ratio shall be adjusted to give a knockmeter reading of 55 to 60. (As any necessary adjustment will increase the knockmeter reading, time can be saved by setting at 55 or in some cases even lower.)

(*b*) The fuel level shall then be adjusted for the position of maximum knock as follows: With a setting of the fuel level, for example, of 1.3 in. on the etched glass scale, the knockmeter needle shall be allowed to reach equilibrium and readings then recorded for this position. Knockmeter readings shall then be obtained and recorded for richer air-fuel ratios by raising the fuel level by 0.1-in. increments to settings of 1.2, 1.1, . . . until the knockmeter reading has decreased at least five divisions from the maximum reading recorded. The fuel level shall then be reset at the position for which the maximum knockmeter reading was recorded in the above, for example, 1.2 in. Starting from this point the same procedure as above shall be followed for leaner air-fuel ratios by setting in turn at 1.3, 1.4, . . . until the knockmeter reading has decreased at least five divisions from the maximum reading recorded. The fuel level shall now be set at the position for which the maximum knockmeter reading has been obtained and recorded or between the two positions for which the same maximum reading was obtained, for example, 1.25 in. This is the position for maximum knock, but it shall be verified at least once by settings at levels 0.1 in. on either side; in the example just taken, at both 1.15 and 1.35 in. If, perchance, the attempted verification indicates, because of higher knockmeter readings at one of these positions, that the setting for maximum knock is in error the procedure shall be repeated. For each setting of the fuel level that is used the knockmeter needle shall be allowed to reach equilibrium before readings are recorded.

(*c*) Finally, the compression ratio shall be adjusted to give a knockmeter reading of 55 to 60. This setting of the compression ratio should be left unchanged for the remainder of the test.

Reference Fuels

13. (*a*) A trial blend[12] of the low- and high-octane reference fuels, based on the expected knock rating of the fuel sample under test, shall be placed in another carburetor float bowl and the engine run on this trial blend. The level of this float bowl shall then be adjusted to the maximum knock position in a manner similar to that described in Section 12.

(*b*) By comparing the knockmeter reading with that obtained for the test sample in Section 12 a second blend of reference fuels differing from the first by not more than two octane numbers shall be placed in the third bowl and the float bowl set at the level for maximum knock. These reference-fuel blends shall be so chosen that the knockmeter reading for the test sample lies between those for the reference-fuel blends.

(*c*) When changing fuels in the containers and fuel system, the fuel shall be drained completely by means of the drain cock. A small portion of the new fuel shall be allowed to flow through the line before closing the drain cock. Air bubbles in the line are indicated by fluctuations in the fuel level. They shall be eliminated by flushing fuel through the drain cock after it has filled the carburetor float bowls. In doing this the drain cock shall be opened and closed rapidly, and care shall be taken not to permit the level of the fuel to go below the range of the sight glass.

Determination of Rating

14. (*a*) With the float bowls set at the air-fuel ratios for maximum knock, series of readings of knock intensity shall be taken on the test sample and on the two reference fuels. In each case the knockmeter needle shall be allowed to reach equilibrium before the reading is recorded.

(*b*) The test sample shall be bracketed between the two blends of reference fuels at least three times, as determined by knockmeter readings. (A simple procedure for doing this is to record readings in order for the second reference fuel, the test fuel, the first reference fuel, the test fuel, the second reference fuel, the test fuel, the first reference fuel.) In changing from one of these fuels to another, at least one minute shall be allowed for the engine and knockmeter to reach equilibrium. With some fuels an appreciably longer time interval may be required.

OCTANE NUMBER

A.S.T.M. Octane Number

15. The knockmeter readings obtained in Section 14 shall be averaged for the test sample and for each of the reference-fuel blends. The octane number of the test sample shall be obtained by interpolation from the averages so obtained, and the nearest whole number reported as the A.S.T.M. octane number. When the interpolated figure ends with 0.50 the nearest even number shall be reported, for example, 68.5 shall be reported as 68 and not 69.

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[12] Extreme care is required to insure thorough mixing of the ingredients of all blends used in this test procedure.

Reproducibility of Results

16. Results obtained by this procedure with different C.F.R. engines and in different laboratories should differ by not more than two octane numbers. While this is the accuracy of the method, its sensitivity may permit detection of differences as small as 0.2 octane number between two test samples of similar characteristics, by direct comparison using the procedure described in Section 14.

MAINTENANCE

Inspection and Maintenance of Apparatus

17. It is recommended that a systematic inspection of the testing apparatus be carried out with the utmost care after not more than 100 hr. of operation. If, with the knock intensity defined in Section 8, these standard test conditions as outlined in Section 10 cannot be maintained, it may be necessary to overhaul the engine after less than 100 hr. of operation. In the inspection the following points shall be emphasized:

(*a*) *Fuel System*.—Any foreign matter in the fuel containers, float bowls, lines, or carburetor shall be removed. (Blowing with air and then flushing the fuel system with gasoline or benzol is a convenient method.)

(*b*) *Manifold Assembly*.—The intake manifold, heater blades, and thermometer bulb shall be inspected, adjusted and cleaned if necessary.

(*c*) *Bouncing Pin*.—Lack of sensitivity or fluctuating knockmeter reading may indicate troubles with the diaphragm, contact points, or spring tensions. The diaphragm may be leaking or may have deteriorated and may need to be replaced. Contact points must be smooth and true.

(*d*) *Breaker Points*.—If necessary, pits should be removed and breaker-point clearance adjusted, or new points installed. The spark-advance setting shall then be checked and reset if necessary.

(*e*) *Spark Plugs*.—The porcelain shall be carefully inspected for cracks, and defective plugs replaced. The spark gap shall be carefully checked, and adjusted if necessary. When plugs are reused any carbon deposit on the metal body of the plug or on the electrodes shall be removed mechanically before making gap adjustments.

(*f*) *Combustion Chamber*.—Carbon deposits shall be removed by scraping.

(*g*) *Piston and Rings*.—Carbon shall be removed from rings and grooves and from both sides of the crown.

(*h*) *Cylinder Wear*.—Cylinders shall be renewed (or rebored for routine testing) when they show a wear of 0.006 in. or lose compression due to being out of round. In no case shall cylinders be rebored to more than 0.03 in. oversize.

(*i*) *Compression Pressure*.—The cause of any abnormal change between inspections shall be investigated and corrected.

(*j*) *Valves*.—Valves shall be removed and reground unless there is a continuous polished line of contact on both the valve and valve seat. The shrouded inlet valve shall be inserted with the shroud opening towards the bouncing pin. Before reassembling, the cylinder shall be inverted with the valves in position and gasoline used to determine whether the valves are tight. After reassembling, the valve-tappet clearances shall be carefully adjusted.

(*k*) *Valve Guides*.—The differences in diameter between the valve stems and their guides shall be 0.0025 ± 0.0005 in. for the intake and 0.0035 ± 0.0005 in. for the exhaust. Valve guides shall be replaced when the upper limits of these clearances are exceeded by more than 0.001 in., as experience has shown that misalignment may result unless particular attention is given to the maintenance of these clearances.

(*l*) *Cooling System.*—Any leaks revealed by inspection shall be repaired.

APPENDIX

SPECIFICATION REQUIREMENTS FOR *ISO*OCTANE AND NORMAL HEPTANE

	*Iso*octane		Normal Heptane	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
A.S.T.M. octane number	99.9	100.1	−0.2	+0.2
Density at 68 F. (20 C.), g. per ml	0.69180	0.69200	0.68370	0.68390
Refractive index at 68 F. (20 C.)	....	....	1.38770	1.38785
Freezing point[a]	−161.55 F. (−107.52 C.)	....	−131.40 F. (−90.78 C.)	....
Distillation:[b]				
Temperature of 50 per cent recovery	....	210.74 F. (99.30 C.)	209.08 F. (98.38 C.)	209.28 F. (98.49 C.)
Temperature increase from 20 to 80 per cent recovery	....	0.11 F. (0.061 C.)	....	0.36 F. (0.20 C.)

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[a] By means of the apparatus and method given in *Scientific Paper No. 520*, Nat. Bureau Standards, pp. 622-624, except that a platinum resistance thermometer shall be used in place of a thermocouple.

[b] By distilling 100 ml. of the sample through a 10-in. jacketed column, a platinum resistance thermometer being inserted so as to measure the condensation temperature of the vapor (see *Research Paper No. 482*, *Journal of Research*, Nat. Bureau Standards, Vol. 9 pp. 459-461 (1932)). Current through the jacket heating coil shall be adjusted so that the reflux from the thermometer shall be 5 to 6 drops per min., and the still-pot heater shall be adjusted to cause distillation to proceed at the rate of 5 ml. per min. The temperature shall be corrected to an atmospheric pressure of 760 mm. of mercury by means of the equation proposed by E. R. Smith, (see *Research Paper No. 1088*, *Journal of Research*, Nat. Bureau Standards, Vol. 20, p. 549 (1938)).

Tentative Methods of Test for

SAPONIFICATION NUMBER[1]

A.S.T.M. Designation: D 94 – 38 T

Issued as Tentative, 1921; Adopted in Amended Form, 1928; Revised, 1936; Reissued as Tentative, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for the determination of saponification number and includes two procedures as follows:

Method A, used for the identification of unmixed animal and vegetable oils, and for determining the quantity of fatty material in compounded products. This method is not applicable in the presence of compounds of sulfur, phosphorus, halogens, or other elements that consume alkali (Note 1).

Note 1.—This method does not give an accurate indication of fatty material present, when the sample contains appreciable amounts of free sulfur, sulfurized oils, etc., which react with the alkali used in this test; such materials combine with potash to increase the saponification number. The presence of hydrogen sulfide as indicated by the odor near the end of the back titration in the saponification test is an indication that reactive sulfur or its compounds are present in the sample, and hence the saponification number obtained will be greater than required for the amount of fatty matter actually present. Unfortunately, in the case of reactive chlorine and phosphorus compounds, no simple indication is given during the test. A gravimetric determination of the actual amount of fatty acids is probably the most reliable method for such compounds (see Section 7 (*b*)).

Method B, used for the determination of the saponification number of new and used electrical insulating oils, and other new and used noncompounded petroleum oils. Method *B* is not to be used for the determination of the saponification number of compounded petroleum products.

Method A

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Erlenmeyer Flask and Condenser.*—An Erlenmeyer flask of 250-ml. capacity to which is attached by means of ground-glass joint an adequate reflux or mushroom-type condenser. The Erlenmeyer flask should preferably be of Pyrex, Jena G-20, or equivalent alkali-resistant glass.

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[1] Under the standardization procedure of the Society, these methods are under the joint jurisdiction of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants and Committee D-9 on Electrical Insulating Materials.

These methods comprise a revision and consolidation of the Standard Method of Test for Saponification Number (D 94 – 36) and the Tentative Method of Test for Saponification Number of Electrical Insulating Oils (Modified Baader Method) (D 438 – 36 T), which standards were accordingly discontinued in 1938.

(*b*) *Hot Plate.*—A suitable hot plate.

Special Solutions Required

3. (*a*) *Alcoholic Potassium Hydroxide Solution* (*1.0 N*).—Dissolve 58 g. of potassium hydroxide "purified by alcohol," in 500 ml. of purified ethyl alcohol (95 per cent). Allow the solution to settle in a dark place. Draw off the clear solution or filter through an asbestos filter and dilute to 1 liter with alcohol (95 per cent). Allow the solution so prepared to stand for at least 20 hr. and then standardize to 1.0 N.

(*b*) *Alcohol.*—Purify ethyl alcohol (95 per cent) with silver oxide in the following manner: Dissolve 1.5 g. of c.p. silver nitrate in about 3 ml. of water, add to 1 liter of alcohol in a glass-stoppered bottle, and mix thoroughly. Dissolve 3 g. of potassium hydroxide purified by alcohol in 10 to 15 ml. of warm alcohol. After cooling, add slowly to the alcoholic silver nitrate solution, stirring slightly. Allow the precipitated silver oxide to settle, siphon off the clear solution and distill on a steam bath.

(*c*) *Standard Hydrochloric Acid Solution* (*0.5 N*).

(*d*) *Phenolphthalein Solution.*—Dissolve 1 g. of phenolphthalein in 100 ml. of purified ethyl alcohol (95 per cent).

Blank Determinations

4. Determinations shall be made in duplicate on the alcoholic potassium hydroxide solution in the following manner: Measure accurately into the flask 25 ml. of alcoholic potassium hydroxide solution from a calibrated pipette. Before the solution is delivered, wipe off the tip and outside of the pipette with a clean filter paper and then rinse out with 25 ml. of neutral alcohol. If a standard burette is used, allow 60 sec. total time for drawing and draining. Connect the flask to the condenser and boil gently while refluxing for 3 hr. Before disconnecting the flask, wash out the condenser with a few milliliters of neutral alcohol; if a Soxhlet is used as the condenser, wash off the tip in the flask. Titrate while hot with 0.5 N HCl using 3 drops of phenolphthalein indicator. The total number of milliliters of 0.5 N HCl required for the blank represents the strength of the alcoholic potassium hydroxide solution.

NOTE 2.—The glassware must be chemically clean and it is recommended that flasks be cleaned with chromic acid cleaning solution and rinsed with distilled water.

Sample

5. A 2 to 3-g. sample shall be used for straight fats or oils, a sample of about 5 g. for oils containing over 30 per cent of fatty oils, and about 10 g. for oils containing less than 30 per cent of fatty oils.

Procedure

6. The saponification number shall be determined as follows: Weigh the oil to plus or minus 0.01 g. by difference, from a small beaker into the saponification flask. Add 25 ml. of alcoholic potassium hydroxide and 25 ml. of neutral alcohol in the manner specified in Section 4 for the blank determinations. Connect to the condenser and boil gently while refluxing for 3 hr. Titrate while hot.

NOTE 3.—Fifty milliliters of A.S.T.M. naphtha[2] free from sulfur or other saponifiable matter may be used with compounded cylinder oils provided a Soxhlet extraction flask is used to collect the naphtha periodically. The Soxhlet flask shall be adjusted, through the addition of glass rodding or beads when necessary, so that it will just overflow with the full quantity of A.S.T.M. naphtha.

Calculations

7. (*a*) The saponification number shall be calculated from the difference

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[2] See Standard Method of Test for Precipitation Number of Lubricating Oils (A.S.T.M. Designation: D 91) of the American Society for Testing Materials, 1936 Book of A.S.T.M. Standards, Part II, p. 944.

between the number of milliliters of 0.5 N HCl required for the determination and the average of the two blanks, as follows:

$$\text{Saponification number} = \frac{D \times 28.05}{W}$$

where:

D = the difference between the number of milliliters of 0.5 N HCl required for the determination and the average of the two blanks, and

W = the weight of oil in grams.

NOTE 4.—The above calculations and data presume a knowledge of the nature of the fat present. In an unknown sample, and particularly when a low saponification number leaves doubt as to whether fat is actually present, the fatty acid may be extracted (as the soap) and recovered for gravimetric determination. For this purpose, the saponified and neutralized solution, obtained as above, shall be handled as in a grease analysis, as described in Section 14 (*b*) of the Standard Methods of Analysis of Grease (A.S.T.M. Designation: D 128) of the American Society for Testing Materials.[3] The fatty acid is thus obtained and may then be used for subsequent identification tests.

(*b*) The percentage of fatty oil (or fat) in a compounded petroleum product can be calculated from the saponification number of such a product only when the saponification number of the fatty oil is known. If the saponification numbers of both fatty oil and compounded oil are known, the following formula shall be used:

$$\text{Percentage of fatty oil} = \frac{C}{F} \times 100$$

where:

C = the saponification number of the compounded oil, and

F = the saponification number of the fatty oil.

For this determination the following values of saponification number may be used:

FATTY OIL	SAPONIFICATION NUMBER
Lard Oil	192 to 198
Tallow	193 to 198
Neatsfoot	193 to 204
Fish	140 to 193
Sperm	120 to 140
Castor	176 to 187
Rapeseed	170 to 179
Soybean	189 to 197
Peanut	186 to 197
Cottonseed	191 to 197
Blown rapeseed	195 to 216
Blown cottonseed	210 to 225
Degras	110 to 210

Reproducibility of Results

8. With care and proper attention to details, duplicate determinations by this method by the same operator may vary plus or minus 0.3 saponification number on compounded oils containing less than 30 per cent compounding; plus or minus 0.5 saponification number on compounded oils containing over 30 per cent compounding; and plus or minus 1.0 saponification number for unmixed fatty oils. For determinations by different operators the permissible variations may be plus or minus 0.5, plus or minus 1.0, and plus or minus 2.0 saponification numbers, respectively. For dark oils, the permissible variations may be double this magnitude.

Method B

Apparatus

9. The apparatus required shall be the same as that described in Section 2.

Special Solutions Required

10. (*a*) *Alcoholic Potassium Hydroxide Solution (0.1 N).*—Dissolve 5.8 g. of potassium hydroxide "purified alcohol," in 500 ml. of purified ethyl alcohol (95 per cent). Allow the solution to settle in a dark place. Draw off the clear solution or filter through an asbestos filter and make up to 1 liter with alcohol (95 per cent). Allow the solu-

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[3] 1937 Supplement to Book of A.S.T.M. Standards, p. 129.

tion so prepared to stand for at least 20 hr. and then standardize to 0.1 *N*.

(*b*) *Alcohol.*—Prepare as described in Section 3 (*b*).

(*c*) *Standard Hydrochloric Acid Solution (0.1 N).*

(*d*) *Alkali Blue Solution.*—Dissolve 0.6 g. of alkali blue *6-B* in 1500 ml. of alcohol (95 per cent) and 1000 ml. of pure benzene.

Blank Determinations

11. Determinations shall be made in duplicate on the alcoholic potassium hydroxide solution in the following manner: Measure accurately into the flask 25 ml. of alcoholic potassium hydroxide solution from a calibrated pipette. Before the solution is delivered, wipe off the tip and outside of the pipette with a clean filter paper and then rinse out with 25 ml. of neutral alcohol. If a standard burette is used, allow 60 sec. total time for drawing and draining. Add 75 ml. of the alkali blue solution. Connect the flask to the condenser and boil gently while refluxing for 30 min. Before disconnecting the flask, wash out the condenser with a few milliliters of neutral alcohol; if a Soxhlet is used as the condenser, wash off the tip in the flask. Titrate while hot with 0.1 *N* HCl. The total number of milliliters of 0.1 *N* HCl required for the blank represents the strength of the alcoholic potassium hydroxide solution.

NOTE 5.—The glassware must be chemically clean and it is recommended that the flasks be cleaned with chromic acid cleaning solution and rinsed with distilled water, and finally rinsed with alkali blue solution.

Procedure

12. The saponification number shall be determined as follows: Weight 5 to 8 g. of the oil to plus or minus 0.01 g. by difference, from a small beaker into the saponification flask. Add 25 ml. of alcoholic potassium hydroxide and 25 ml. of neutral alcohol in the manner specified for the blank determination. Then add 75 ml. of alkali blue solution. Connect the flask to the condenser and boil gently while refluxing for 30 min. Before disconnecting the flask, wash out the condenser with a few milliliters of neutral alcohol; if a Soxhlet is used as the condenser, wash off the tip in the flask. Titrate while hot with 0.1 *N* HCl. Carry out the titrations as quickly and with as little splashing as possible, because the alkali blue solution is sensitive to carbon dioxide and air contamination. Ignore any change after the first end point.

Calculation

13. The saponification number shall be calculated from the difference between the number of milliliters of 0.1 *N* HCl required for the determination and the average of the two blanks, as follows:

$$\text{Saponification number} = \frac{M \times 5.611}{O}$$

where:

M = the difference between the number of milliliters of 0.1 *N* HCl required for the determination and the average of the two blanks, and

O = the weight of oil in grams.

Reproducibility of Results

14. With care and proper attention to details, duplicate determinations by this method by the same operator should agree within 0.1 saponification number. For determinations by different operators the permissible variation may be double this amount.

Tentative Method of Test for

SEDIMENT IN FUEL OIL BY EXTRACTION[1]

A.S.T.M. Designation: D 473 - 38 T

ISSUED, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for the determination of sediment in fuel oils by extraction with 90 per cent benzol.

Apparatus

2. The extraction apparatus, Fig. 1, shall consist of the following:

(*a*) *Extraction Flask.*—An Erlenmeyer flask of 1-liter capacity.

(*b*) *Condenser.*—A block-tin coil condenser as shown in Fig. 1.

(*c*) *Extraction Thimble.*—An alundum (porous grade) thimble[3] 1 in. in diameter by 2¾ in. in height, weighing not less than 15 nor more than 17 g. The thimble shall be suspended from the condenser coil by means of a platinum wire so that it hangs approximately 1¾ in. above the extracting solvent and 1¾ in. below the condenser coil.

(*d*) *Source of Heat.*—A suitable source of heat to vaporize benzol, such as a steam bath or electric hot plate.

Procedure

3. The alundum thimble before use shall be given a preliminary extraction, allowing the solvent to drip from the thimble for at least 1 hr. The thimble shall then be dried for 1 hr. at a temperature of 105 to 110 C., cooled to room temperature, and weighed to the nearest 0.0001 g. This extraction shall be repeated until the weights of the thimble after two successive extractions, do not differ by more than 0.0002 g. Approximately 10 g. of the sample[4] shall be placed in the thimble and the weight determined to the nearest 0.01 g. The thimble shall be placed in the extraction apparatus and the sample extracted with 90 per cent benzol until the solvent dropping from the thimble is colorless.[5] The rate of extraction shall be such that the surface of the mixture of oil and benzol in the thimble does not rise higher than to within ¾ in. of the top. After the

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] Accepted for publication as tentative by Committee E-10 on Standards, April 27, 1938.

[3] Alundum thimbles listed as No. 5163 RA 98 by the Norton Co., Worcester, Mass., have proved satisfactory.

[4] The portion of the sample taken for test shall be thoroughly representative of the sample. An estimated 10-g. portion of the sample should be placed in the thimble as soon as possible after the sample has been thoroughly mixed. No attempt should be made to adjust this estimated 10-g. portion to any exact predetermined amount.

[5] When testing oils having high water content, difficulty due to clogging of the thimble with moisture may be overcome by interrupting the extraction when this occurs and drying the thimble in an oven before proceeding further with the extraction.

extraction is completed the thimble shall be dried for 1 hr. at 105 to 110 C., cooled, and weighed to the nearest 0.0001 g. The extraction shall be repeated, allowing the solvent to drip from the thimble for at least 1 hr. but not longer than $1\frac{1}{4}$ hr., the thimble dried, cooled, and weighed as above. This extraction for a 1-hr. period shall be repeated, if necessary, until the weights of the dried thimble and sediment after two successive extractions do not differ by more than 0.0002 g. For referee tests a new extraction thimble shall be used. For routine tests thimbles may be used for a number of successive determinations on different samples, the extraction to constant weight for one determination being considered as the preliminary extraction for the succeeding determination. When the accumulation of sediment becomes objectionable and the combustible portion is removed by heating to a dull red heat (preferably in an electric furnace), the thimble shall be subjected to a preliminary extraction before being used for another determination.

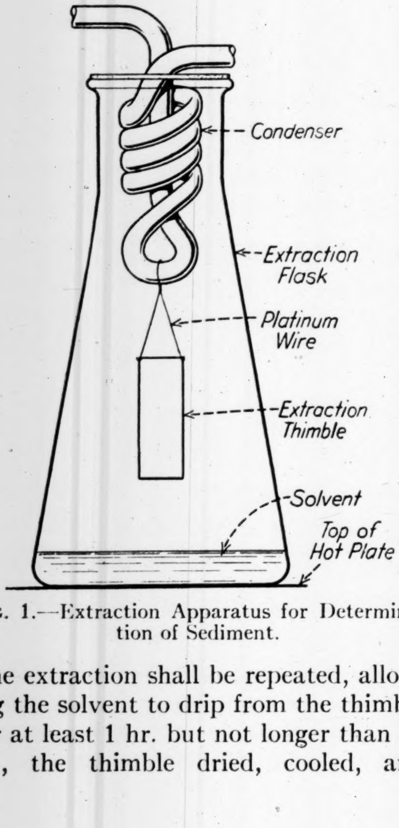

FIG. 1.—Extraction Apparatus for Determination of Sediment.

Reproducibility of Results

4. With proper attention to details of methods of procedure, check results by the same operator should not deviate from the mean value by more than the following amounts:

SEDIMENT, PER CENT	DEVIATION FROM MEAN VALUE
0.00 to 0.25	±0.01
0.26 to 0.50	±0.02

Tentative Method of Test for

UNSULFONATED RESIDUE OF PLANT SPRAY OILS[1]

A.S.T.M. Designation: D 483 – 38 T

ISSUED, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for use in determining the amount of unsulfonated residue of plant spray oils.

Special Solutions Required

2. (*a*) *Sulfuric Acid* (*37 N*).—Prepare 37 *N* H_2SO_4 by blending reagent-grade fuming and concentrated sulfuric acids to 98.61 ± 0.1 per cent H_2SO_4, as determined by titration.

(*b*) *Sulfuric Acid* (*sp. gr. 1.84*).

Apparatus

3. The apparatus shall consist of the following:

(*a*) *Sample Bottles.*—Ordinary 4-oz. glass bottles for oil samples.

(*b*) *Pipette.*—One 5-ml. pipette, precision grade, calibrated in the laboratory to deliver 5 ± 0.005 ml. of oil at 77 F. (25 C.).

(*c*) *Burette.*—One 50-ml. burette, graduated in 0.1-ml. divisions.

(*d*) *Test Bottles.*—The test bottles shall be made of good quality glass and the preferred form shall conform to the dimensions given in Fig. 1.[2] The capacity to base of neck shall be 45 to 50 ml. The graduated portion of the bottle shall contain 5 ± 0.025 ml. (at a temperature of 77 F. (25 C.)) and shall be graduated in 100 divisions, the first and each succeeding tenth line to extend at least three-fourths of the distance around the neck and to be numbered from the bottom 5, 10, etc. Within the range from 0 to 50, the maximum error in volume shall not be greater than 0.025 ml. The graduation marks shall be clear and fine, not more than 0.3 mm. in width. As an alternative, the standard "6-in., 9-g., 50 per cent x $\frac{1}{2}$ cream bottle" may be used. In this bottle the maximum error in volume of the graduated portion shall not be greater than 0.05 ml. to conform to the established standard. The bottom of the bottles shall have a ground area of at least 2 sq. cm. for numbering.

(*e*) *Water Baths.*—Two water baths, as follows:

A water bath maintained at 77 ± 0.5 F. (25 ± 0.3 C.) and of such depth that the 4-oz. bottles containing samples for test may be immersed, the oil level being well below the surface of the water.

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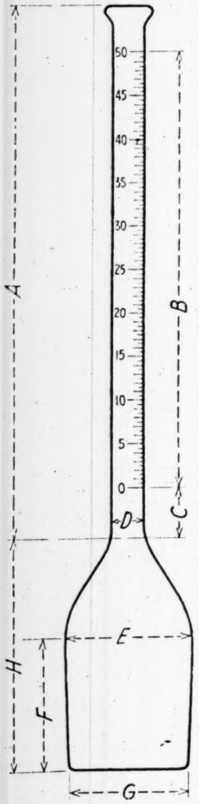
[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] These bottles are commonly known as "9-in., 9-g., 50 per cent x $\frac{1}{2}$ cream bottles."

A water bath maintained at 211 to 212 F. (99.4 to 100 C.), of sufficient depth to permit complete immersion of the body of the test bottle and equipped with clamps to hold the bottle rigidly in a vertical position.



A = 16 ± 0.5 cm.
B = 13 ± 1.0 cm.
C = not less than 0.5 cm.
D = 0.70 ± 0.05 cm., inside diameter.
E = not more than 3.75 cm.
F = approximately 4 cm.
G = not more than 3.75 cm.
H = approximately 6.5 cm.
A + H = 22.5 ± 0.5 cm.

FIG. 1.—Test Bottle.

(*f*) *Centrifuge.*—A centrifuge capable of whirling two test bottles filled with acid at a speed of 1000 r.p.m. The preferred form of centrifuge shall have a diameter of swing (at the base of whirling bottles) sufficient to accommodate the test bottles without danger of interference when placed in opposite carriers. The centrifuge shall be of good design and rugged construction, so that it may be operated without danger. The bottle carrier shall be so designed that the test bottles may be cushioned with rubber or other suitable material. A strong metal shield, approximately 2 ft. in diameter, shall be placed around the centrifuge as a protection against injury if breakage should occur.

Procedure

4. (*a*) A small portion (15 or 20 ml.) of the sample shall be placed in a clean, dry, 4-oz. bottle, which shall then be immersed in the water bath at 77 F. (25 C.) until the sample has attained bath temperature. Exactly 5 ml. of the sample shall then be drawn into the clean, dried, especially calibrated pipette and delivered into the clean, dried test bottle.

NOTE.—As an alternative procedure, 5 ml. of the sample may be obtained by weighing. The weight of the sample shall agree within plus or minus 0.005 g. of the weight of 5 ml. of the oil at 77 F. (25 C.), as calculated from its specific gravity.

(*b*) Then 5 ml. of 37 *N* H_2SO_4 shall be slowly added to the test bottle from the burette in such a way as to wash down any oil remaining in the neck of the bottle. The test bottle shall then be shaken for 2 or 3 sec., grasping the neck between the thumb and index finger and swinging the bottle through an arc of approximately 20 deg. so that the bottom of the bottle passes through a distance of $2\frac{1}{2}$ to $3\frac{1}{2}$ in. The speed of shaking shall be maintained at from 240 to 300 cycles per min.[3] The temperature of this acid-oil mixture shall not be allowed to approach 212 F. (100 C.), as indicated by the bottle becoming too warm to touch, or by the contents foaming excessively. The bottle may be cooled in ice water if necessary.

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[3] A mechanical shaking device may be used instead of hand shaking if desired, provided that equally accurate results are obtained.

(*c*) The procedure outlined in Paragraph (*b*) shall be repeated until a total of 20.0 ml. of 37 *N* H_2SO_4 has been added, the test bottle being placed finally in the water bath at 212 F. (100 C.). These several additions of acid shall be made without delay.

(*d*) After the test bottle has been in the bath for 10 min. it shall be removed, shaken in the manner prescribed in Paragraph (*b*) for exactly 10 sec., and replaced immediately in the water bath at 212 F. (100 C.). If the sample boils or foams over at this stage, it shall be discarded and the test repeated.

(*e*) The procedure outlined in Paragraph (*d*) shall be repeated for a total of six immersions and shakings, but the bottle shall not be replaced in the bath after the last shaking.

(*f*) Sufficient H_2SO_4 (sp. gr. 1.84) shall be added to the contents of the test bottle to raise the liquid level in the neck to the 50 mark, that is, the top graduation. The bottle and contents shall then be placed in the centrifuge and whirled at a speed of approximately 1000 r.p.m. for 10 min. The bottle shall then be removed from the centrifuge and placed in the water bath at 77 F. (25 C.) so that the contents of the bottle are immersed below the surface of the water. After 10 min. the bottle shall be removed from the bath and the volume of oil read, with the aid of a reading glass if preferred, to within 0.01 ml. which is one-fifth of a division. The centrifuging process shall be repeated until the volume of oil is constant.

(*g*) After a constant oil volume has been obtained by centrifuging, the reading of the bottom of the oil level shall be subtracted from the reading of the top and the difference multiplied by two. This value so obtained is the percentage of unsulfonated residue, and shall be reported to the nearest 0.1 per cent. Due attention shall be paid to calibration corrections.

Precautions

5. (*a*) It is extremely important that all glassware used in the test shall have been thoroughly cleaned and dried before use. Acetone has proved satisfactory for this purpose.

(*b*) If at any time during the test even the smallest quantity of oil or acid-oil mixture is lost, the sample shall be discarded and the test repeated.

(*c*) The rate of whirling may be decreased to avoid breakage of the test bottles. In all cases, however, the centrifuging shall be continued until a constant reading of the volume of oil is obtained. Ordinarily, centrifuging at 1000 r.p.m. for 10 min. is sufficient, but occasionally oils are encountered which do not separate readily and completely from the acid sludge.

Reproducibility of Results

6. For the most satisfactory results, determinations shall be made in duplicate, and should agree within 1.0 per cent unsulfonated residue based upon the original sample. This accuracy should be expected only with proper care and strict attention to details. Determinations by different operators should agree within 2.0 per cent.

Tentative Method of Test for

VAPOR PRESSURE OF PETROLEUM PRODUCTS (REID METHOD)[1]

A.S.T.M. Designation: D 323 - 38 T

Issued, 1930; Revised, 1931, 1932, 1935, 1937, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for the determination of the vapor pressure of volatile, non-viscous petroleum products.

Note 1.—Two sampling procedures are described in this method, one for products having vapor pressures of 26 lb. or less and the other for products of higher vapor pressures. Sections 10 to 15, inclusive, shall be followed for products in the first group, and Sections 10, 13, 21 and 22 for products in the second group. In case of doubt, the maximum vapor-pressure specification of the product to be tested shall determine which sampling procedure to employ without regard to the numerical value obtained in the test.

Apparatus

Vapor-Pressure Bomb

2. The vapor-pressure bomb consisting of two sections or chambers, an upper section or air chamber, and a lower section or gasoline chamber, shall conform to the following requirements:

(*a*) *Air Chamber.*—The upper section, or air chamber, shown in Fig. 1, shall be a cylindrical vessel 2 to $2\frac{1}{8}$ in. in diameter and $10 \pm \frac{1}{8}$ in. in length, inside dimensions. In one end of the air chamber a $\frac{1}{4}$-in. standard pipe thread shall be tapped, to receive the gage coupling. Other means of connecting the air chamber with the pressure gage may be employed, provided the requirements of Paragraphs (*e*) and (*f*) are fulfilled. In the other end of the air chamber an opening approximately $\frac{1}{2}$ in. in diameter shall be provided for purposes of coupling with the gasoline chamber. The nature of this opening will depend upon the method of coupling employed. The air chamber must drain completely from either end when held in a vertical position and for this reason the ends may be slightly convex.

(*b*) *Gasoline Chamber.*—The lower section, or gasoline chamber, shown in Fig. 1 (*a*), shall be a cylindrical vessel of the same inside diameter as the air chamber and $2\frac{1}{2} \pm \frac{1}{16}$ in. in inside length. In one end of the gasoline chamber an opening approximately $\frac{1}{2}$ in. in diameter shall be provided for purposes of coupling with the air chamber. The nature of this opening will depend upon the method of coupling employed. The other end of the gasoline chamber shall be completely closed. The gasoline chamber must drain completely when inverted and for this reason the top may be slightly convex.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

This method comprises a consolidation of, and replaces the former Tentative Method of Test for Vapor Pressure of Natural Gasoline (Reid Method) (A.S.T.M. Designation: D 323 - 32 T) and the Tentative Method of Test for Vapor Pressure of Motor and Aviation Gasoline (Reid Method) (A.S.T.M. Designation: D 417 - 35 T), which methods were accordingly discontinued in 1937.

(*c*) *Gasoline Chamber for Sampling from Closed Vessels.*—For this use the lower section, or gasoline chamber, shown in Fig. 1 (*b*), shall be the same as described in Paragraph (*b*) except that a $\frac{1}{4}$-in. needle valve shall be attached near the bottom of the gasoline chamber and a $\frac{1}{2}$-in. gate valve shall be introduced in the coupling between the chambers as illustrated in Fig. 1 (*b*). The vertical dimensions of the gasoline chamber proper in Fig. 1 (*b*) shall be such that the assembly fulfills the requirements of Paragraph (*e*) for the type of construction illustrated. The type of gasoline chamber shown in Fig. 1 (*b*) may be used for immersion sampling.

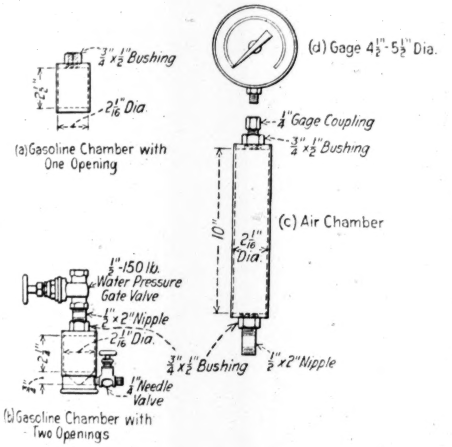

FIG. 1.—Vapor-Pressure Bomb, Screw-Coupling Type.

(*d*) *Method of Coupling Air and Gasoline Chambers.*—Any method of coupling the air and gasoline chambers may be employed, for example, a simple thread, a union, or a clamp. The sole provision in this respect is that the assembly shall be free from leaks under the conditions of test. Responsibility for freedom from leaks rests with the user.

(*e*) *Volumetric Capacity of Air and Gasoline Chambers.*—The ratio of the volume of the air chamber to the volume of the gasoline chamber shall be between the limits of 3.8 and 4.2. To determine the volume of the air chamber, insert a $\frac{1}{4}$-in. plug in the gage coupling, invert the chamber, fill with water up to and including the portion of the coupling device attached permanently to the air chamber and then carefully measure the volume of water. To determine the volume of the gasoline chamber, fill with water up to and including the portion of the coupling device attached permanently to the gasoline chamber, and then carefully measure the volume of water.

NOTE 2.—In determining capacities for apparatus shown in Fig. 1 (*b*), the capacity of the gasoline chamber shall be considered as that below the gate-valve closure. The volume above the gate-valve closure including the portion of the coupling permanently attached to the gasoline chamber shall be considered as a part of the air-chamber capacity.

(*f*) *Checking for Freedom from Leaks.*—Before placing new apparatus in service and as often as necessary thereafter, the assembled vapor-pressure bomb shall be checked for freedom from leaks by filling with air to 100-lb. gage pressure and completely immersing in a water bath. Only apparatus which will stand this test without leaking shall be used.

Pressure Gage

3. (*a*) The pressure gage shall be a Bourdon-type spring gage of test-gage quality $4\frac{1}{2}$ to $5\frac{1}{2}$ in. in diameter. The

range of the pressure gage used shall be governed by the vapor pressure of the sample being tested, as follows:

Vapor Pressure, psi. at 100 F.	Gage to be Used[a]		
	Scale Range	Numbered Intervals	Intermediate Graduations
12 and under	0 to 15 lb.	3 lb.	0.1 lb.
10 to 36	0 to 45 lb.	5 lb.	0.2 lb.
30 to 55	0 to 60 lb.	10 lb.	0.25 lb.
50 and higher	0 to 100 lb.	10 lb.	0.5 lb.

[a] A gage of 0 to 30-lb. range, 5-lb. numbered intervals and 0.2-lb. intermediate graduations may be used for products of from 10 to 26-lb. vapor pressure.

(*b*) Only accurate gages shall be continued in use. When the "gage correction" (Section 18 (*h*)) exceeds 1 per cent of the scale range, the gage shall be considered inaccurate.

Cooling Bath

4. A cooling bath shall be provided of such dimensions that the sample containers and gasoline chambers may be completely immersed. Means for maintaining the bath at a temperature of 32 to 40 F. (0 to 4.4 C.) shall be provided.

Water Bath

5. The water bath shall be of such dimensions that the vapor-pressure bomb may be immersed to at least 1 in. above the top of the air chamber. Means for maintaining the bath at a constant temperature of 100 ± 0.2 F. (37.8 ± 0.1 C.) shall be provided.

Water-Bath Thermometer

6. The thermometer for measuring the water-bath temperature shall conform to the following requirements:

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISIONS: Range 94 to 108 F., subdivisions in 0.2 F.

TOTAL LENGTH: 252 to 256 mm. (9.92 to 10.08 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.

Length, 25 to 35 mm. (1.0 to 1.4 in.).

Diameter, not less than 5 mm. (0.20 in.) and not greater than that of stem.

DISTANCE TO LOWEST SPECIFIED GRADUATION FROM BOTTOM OF BULB: 135 to 150 mm. (5.3 to 5.9 in.).

DISTANCE TO HIGHEST SPECIFIED GRADUATION FROM TOP OF THERMOMETER: 20 to 35 mm. (0.8 to 1.4 in.).

CONTRACTION CHAMBER: To be of long narrow type, top to be not more than 60 mm. (2.36 in.) above bottom of bulb, mercury to stand in contraction chamber at 32 F.

EXPANSION CHAMBER: To permit heating the thermometer 90 F. above highest temperature on scale, and in all cases to permit heating to 212 F.

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION. All lines, figures and letters clear cut and distinct. The first and each succeeding 1 F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2 F.

IMMERSION: Total.

SPECIAL MARKING: The A.S.T.M. Reid-vapor-pressure test point of 100 F. to be numbered in red, other graduations and figures in black. A serial number and the manufacturer's name or trade-mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale shall not exceed 0.2 F.

STANDARDIZATION: The thermometers are to be standardized for the condition of total immersion. Correction for emergent stem shall not be applied.

CASE: Each thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Reid-Vapor-Pressure Thermometer."

NOTE 3.—As an alternate, the oil-tube thermometer, with a range of 94 to 108 F. (34 to 42 C.) described in the Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88) of the American Society for Testing Materials,[2] may be used.

Air Chamber Thermometer

7. The thermometer for measuring the temperature of the air chamber shall conform to the following requirements:

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[2] 1938 Supplement to Book of A.S.T.M. Standards, p. 148.

TYPE: Etched stem, glass.
LIQUID: Mercury.
TOTAL LENGTH: 254 to 305 mm. (10.0 to 12.0 in.).
RANGE AND SUBDIVISIONS: Range −40 F. or −30 F. to +120 F. or +130 F.; subdivisions in 1 F.
STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.24 to 0.28 in.).

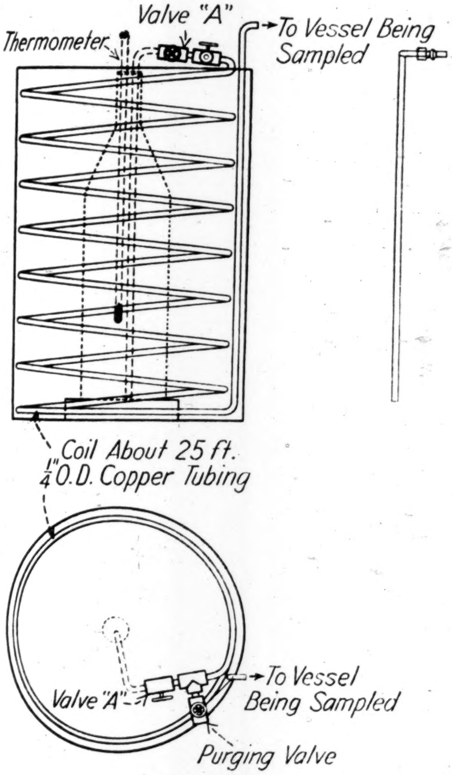


FIG. 2.—Chilled Sampling Apparatus.

BULB: Corning normal or equally suitable thermometric glass.
Length, not over 25 mm. (1.0 in.).
IMMERSION: Total.
SCALE ERROR: The error at any point of the scale shall not exceed 0.5 per cent of the scale range.

Chilled Sampling Apparatus

8. The chilled sampling apparatus shall consist of a bath of sufficient size to accommodate both the sample container and a cooling coil formed of $\frac{1}{4}$-in. outside diameter, No. 20 gage copper tubing. One end of the cooling coil shall be provided with connections suitable for attaching to the tank sampling connection and the other end shall be provided with a $\frac{1}{8}$-in. needle valve of good quality. For introducing the sample into the container this valve shall have at its open end a removable tube of $\frac{1}{4}$-in. outside diameter copper tubing of sufficient length to reach the bottom of the sample container. A bath of suitable design is shown in Fig. 2.

Sample Containers and Transfer Connections

9. The two types of containers for obtaining samples of gasoline for vapor-pressure tests shall conform to the following general requirements: The containers shall be at least 1 qt. in size and of ample strength to withstand the pressures to which they may be subjected. The construction shall be such that the containers may be easily and securely sealed. Container openings in all cases shall be of a type which will permit the replacement of the cap, stopper, or plug with the connections provided for transferring samples to the gasoline chamber.

(*a*) *Open-Type Containers.*—Containers classed as open-type containers shall be provided with a single opening. Such containers shall be of a type which will readily permit sampling by immersion.

The sample-transfer connection for the open-type container shall consist of two tubes assembled in a replacement cap or stopper. One of these tubes, the air tube, shall extend to the bottom of the sample container. The second tube, the liquid-delivery tube, shall be flush with the inside face of the cap or stopper and shall extend beyond the cap or stopper for a sufficient length to reach to the bottom of the gasoline chamber in the sample-transfer operation.

(*b*) *Closed-Type Containers.*—Containers classed as closed-type containers shall be provided with two openings, one in each end or the equivalent thereof, fitted with suitable valves.

The sample-transfer connection for the closed-type container shall consist of a single tube with fittings suitable for connection to one of the openings of the sample container, the tube being of sufficient length to reach to the bottom of the gasoline chamber in the sample-transfer operation.

SAMPLING

10. The following general remarks apply to all sampling for Reid-vapor-pressure determinations. The extreme sensitivity of vapor-pressure measurements to losses through evaporation and to slight changes in composition is such as to require the utmost precautions and the most meticulous care both in the obtaining and in the handling of samples to insure their being representative. Official samples shall be taken by, or under the immediate direction of, a person of judgment, skill and previous experience in sampling for vapor-pressure measurements.

Sampling Open Tank Cars and Small Open Tanks

11. Open-type sample containers (Section 9) shall be used for sampling open tank cars and small open tanks. The empty sample container shall first be immersed in the car or tank of liquid to be tested and allowed to fill while being lowered and raised through the liquid. The first filling is for the purpose of washing the container thoroughly. The container shall be emptied and then refilled. On this second filling the sample container shall be lowered and raised at such a rate that it will be nearly but not quite full when withdrawn. Enough of the contents shall be poured off immediately so that the portion remaining shall fill the sample container to not less than 70 per cent and not more than 80 per cent of its capacity. The sample container shall be promptly sealed.

Sampling Other Vessels

12. For obtaining samples from other sizes or types of vessels than those described in Section 11, the following general remarks apply: The methods of sampling, points of sampling, and number of samples shall be as agreed upon by the contracting parties but in all cases the procedure followed shall result in obtaining representative samples. Because of the sensitivity of this method of test to handling losses, compositing of samples to arrive at an average vapor pressure for the contents of large vessels shall not be permitted.

(*a*) *Sampling into Open-Type Sample Containers.*—Open-type sample containers (Section 9) shall be used for obtaining samples from large open tanks and may be used for obtaining samples from closed or pressure tanks. In both cases the containers shall be rinsed with the product to be sampled immediately prior to obtaining the sample. The container shall then be refilled. If necessary, enough of the contents shall be poured off immediately so that the portion remaining shall fill the sample container to not less than 70 per cent and not more than 80 per cent of its capacity. The sample container shall be promptly sealed. The sampling from closed or pressure tanks shall be conducted under such conditions that the sample in the sample container is at a temperature of 32 to 40 F. (0 to 4.4 C.) for the duration of sampling. If this requires the use of the chilled sampling apparatus (Section 8 and Fig. 2), sufficient volume shall be wasted through the cooling coil to insure complete purging. During the sampling operation, the outlet valve (*A*, Fig. 2) shall be throttled so as to maintain a pressure in the chilling coil equivalent approximately to that in the vessel being sampled.

(*b*) *Sampling into Closed-Type Sample Containers.*—Closed-type sample containers (Section 9) may be used for obtaining samples from closed vessels by either of two methods, that is, purging with the gasoline being sampled or by water displacement. The water displacement method is preferable where the flow involved in the purging procedure may create a hazard.

When the purging method is used, the inlet valve of the container shall be connected to the sampling line from the pressure vessel. During the sampling operation, the outlet valve of the container shall be throttled so as to maintain a pressure in the container equivalent approximately to that in the vessel being sampled. The sample shall be drawn by allowing the product to flow through the sampling system until a volume equal to at least twice that of the sample container has been passed. Valves shall then be closed and the container disconnected. Enough of the contents shall be withdrawn immediately so that the portion remaining shall fill the sample container to not less than 70 per cent and not more than 80 per cent of its capacity. Should the vapor pressure of the product be insufficient to force liquid from the container, it shall be permissible to open both valves to facilitate the withdrawal of the amount specified. The sample container shall be promptly sealed.

When the water displacement method is used, the procedure shall be as follows: Previous to sampling, the container shall be completely filled with water which shall be maintained at a temperature equal to or lower than that of the gasoline to be sampled. When sampling, the top or inlet valve of the container shall be connected to the source of the sample as directly as possible, the connection being made while a small amount of the liquid to be sampled is flowing through the fittings comprising the connection. All valves on the inlet side of the container shall then be opened wide and the bottom or outlet valve opened slightly thus allowing the water to be displaced slowly by the sample entering the container. Flow shall be so regulated that there is no appreciable diminution of pressure in the container. As soon as gasoline discharges from the outlet, the outlet valve shall be closed, followed in succession by closure of the inlet valve and the valve on the sample tap. The container shall then be disconnected, taken to a safe locality and 20 to 30 per cent of its contents removed. The sample container shall then be promptly sealed for transportation to the point where the test is to be completed.

Care of Samples

13. Samples shall be put in a cool place as soon as possible after they have been obtained and held there until all tests have been completed. Samples in leaky containers shall not be considered for tests but shall be discarded and new samples obtained.

Saturation of Samples in Sample Containers

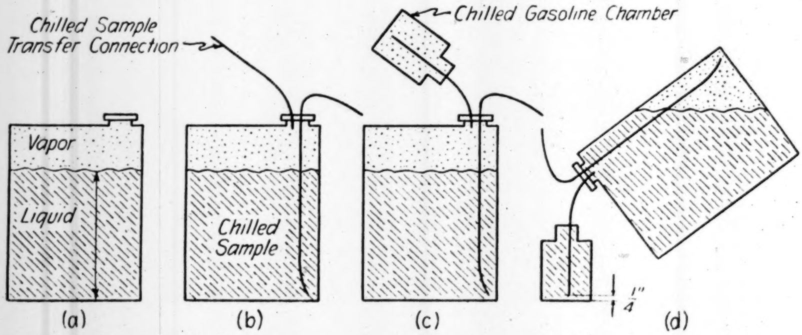
14. Prior to the Reid-vapor-pressure determinations, the sample container shall be immersed in the cooling bath (Section 4) held at a temperature of 32 to 40 F. (0 to 4.4 C.) for a sufficient time to allow the liquid to reach the bath temperature. The container shall then be unsealed for 5 sec., resealed, shaken vigorously, and then returned to the bath.

Sample Transfer

15. (*a*) The sample shall be transferred from the sample container to the gasoline chamber as described in the following Paragraphs (*b*) to (*d*). This operation shall be performed when the apparatus is being assembled for test and fits between the steps described in Section 17 (*d*) and (*e*).

(*b*) The gasoline chamber and the sample-transfer connection shall be chilled in the cooling bath (Section 4).

(*c*) With everything in readiness the chilled sample container shall be removed from the bath, the cap, stopper or plug shall be removed and the precooled transfer connection immediately attached to the sample container. (See Fig. 3.)



(a) Sample Container Prior to Transfer of Sample

(b) Sealing Closure Replaced by Sample Transfer Connection

(c) Gasoline Chamber Placed Over Liquid Delivery Tube

(d) Position of System for Sample Transfer

FIG. 3.—Simplified Sketches Outlining Method of Transferring Sample to Gasoline Chamber from Open-Type Containers.

(*d*) The chilled gasoline chamber shall then be placed over the sample-delivery tube of the transfer connection. The entire system thall then be rapidly inverted so that the gasoline chamber is finally in an upright position with the delivery tube extending to within $\frac{1}{4}$ in. of the bottom of the gasoline chamber. In the case of closed-type containers the valves (or valve) shall not be opened until the system has reached its final position (Note 4). The gasoline chamber shall be filled to overflowing.

NOTE 4.—The valve on the sample-delivery tube should be opened first. If liquid does not flow, it will be necessary to open the second valve.

PROCEDURE

Preparation of Apparatus

16. If tests have been previously conducted in the apparatus to be used, the procedure prescribed in the following Paragraphs (*a*) to (*c*) shall be followed to prepare the apparatus for the next test. These operations are most conveniently done at the conclusion of each test.

(*a*) The air chamber, gasoline chamber and pressure gage shall be disconnected.

(*b*) The pressure gage shall be purged of residual gasoline by directing a small jet of air into its Bourdon tube for at least 5 min.

(*c*) The air chamber shall be thoroughly purged of liquid gasoline and gasoline vapors by filling the air chamber with warm water (above 90 F.) and allowing it to drain, repeating the operation at least five times (Note 5).

NOTE 5.—If this purging is done in a bath be sure to avoid small and unnoticeable films of floating gasoline by keeping the bottom and top openings of the air chamber closed as they pass through the surface of the water.

"Initial Air Temperature"; Assembly of Apparatus

17. (*a*) The air chamber shall be rinsed (see Note, Section 16 (*c*)) with clean water (temperature optional).

(*b*) The pressure gage shall then be attached to the air chamber.

(*c*) The air thermometer shall next be inserted in the air chamber for three-fourths of its length. The bulb shall not be permitted to rest on the wall of the air chamber.

(*d*) The temperature of the air and water vapor in the air chamber shall be read. Since it is absolutely necessary that this temperature shall be the actual temperature of the air and water vapor in the air chamber at the time of final assembly (Paragraph (*e*)), the air thermometer shall have been in the air chamber (Paragraph (*c*)) at least 5 min. before the temperature is read. This temperature shall be recorded as the "initial air temperature."

(*e*) The gasoline chamber, immediately (note exception in Section 22) after being filled with the sample (Section 15 (*b*), 21 (*b*) or (*c*)), shall be attached to the air chamber with the pressure gage attached (Paragraph (*b*)).

NOTE 6.—If a threaded coupling is employed a little water-soluble grease or other low-vapor-pressure lute on the threads will materially assist in making a tight connection.

(*f*) The time interval between the operations prescribed in Paragraphs (*d*) and (*e*) shall be as short as possible.

Vapor-Pressure Determination

18. (*a*) The assembled vapor-pressure bomb shall be turned upside down and shaken vigorously in this position. This operation shall be repeated several times.

(*b*) The bomb shall then be righted and immersed in the water bath to at least 1 in. above the top of the air chamber (Section 5).

(*c*) The water bath shall be maintained throughout the vapor-pressure determination at a constant temperature of 100 ±0.2 F. (37.8 ± 0.1 C.) as determined by the bath thermometer (Section 6) well immersed in the bath.

(*d*) While the bomb is immersed in the bath, it shall be closely observed for leaks. Liquid leaks are much more difficult to detect than vapor leaks and since the much used coupling device is normally in the liquid section of the apparatus it shall be given particular attention. When, at any time in the course of the test, a leak is detected the test shall be discarded.

(*e*) After 5 min. the bomb shall be withdrawn from the bath, inverted, shaken vigorously and replaced in the bath. Thereafter, at intervals of not less than 2 min., the bomb shall be withdrawn from the bath, inverted, shaken vigorously and replaced in the bath. This vigorous shaking shall be performed quickly to avoid cooling the bomb and its contents.

(*f*) Prior to each removal of the bomb from the bath, the gage reading shall be observed. The gage shall be tapped lightly prior to each reading.

(*g*) These operations shall be continued for at least 20 min. to insure equilibrium. After this time if consecutive gage readings observed are constant, the value of the readings shall be recorded as the "uncorrected vapor pressure" of the sample under test.

(*h*) The pressure gage shall be immediately removed from the bomb and its reading at the "uncorrected vapor pressure" compared with that of a mercury column. The correction thus determined shall be recorded as the "gage correction."

CALCULATION

Calculation

19. (*a*) To calculate the "Reid vapor pressure" of the sample under test, the "uncorrected vapor pressure" (Section 18 (*g*)) shall be corrected for the pressure-gage error (Section 18 (*h*)) and for the change in the pressure of the water vapor and air in the air chamber due to the differences between the "initial air temperature" and the temperature of the water bath. Table I shows the corrections to apply for "initial air temperatures" ranging from 32 to 110 F. (0 to 43.3 C.). The value resulting from the application of these corrections shall be recorded as the "Reid vapor pressure."

TABLE I.—CORRECTIONS TO CONVERT UNCORRECTED VAPOR PRESSURES TO REID VAPOR PRESSURES.

Initial Air Temperature[a]	Corrections in Pounds per Square Inch for Various Temperatures as Calculated for Normal Barometric Pressures of:				
	760 mm.	745 mm.	700 mm.	650 mm.	600 mm.
32 F. (0 C.)	−2.9	−2.9	−2.7	−2.6	−2.5
40 F. (4.4 C.)	−2.6	−2.6	−2.4	−2.3	−2.2
50 F. (10 C.)	−2.2	−2.2	−2.1	−2.0	−1.9
60 F. (15.6 C.)	−1.8	−1.8	−1.7	−1.6	−1.6
70 F. (21.1 C.)	−1.4	−1.4	−1.3	−1.3	−1.2
80 F. (26.7 C.)	−1.0	−1.0	−1.0	−0.9	−0.9
90 F. (32.2 C.)	−0.5	−0.5	−0.5	−0.5	−0.5
100 F. (37.8 C.)	0	0	0	0	0
110 F. (43.3 C.)	+0.6	+0.6	+0.5	+0.5	+0.5

$$\text{Correction Factor} = \frac{(P_a - P_t)(t - 100)}{460 + t} - (P_{100} - P_t)$$

where t = the air chamber temperature at beginning of test, deg. Fahr.

P_t = the vapor pressure of water, pounds per square inch, at t deg. Fahr.

P_{100} = the vapor pressure of water, pounds per square inch, at 100 F. (37.8 C.)

P_a = the normal barometric pressure in pounds per square inch at place where test is conducted.

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[a] For intermediate air temperatures, the corrections should be interpolated to the nearest 0.1 psi.

Example.—If the "uncorrected vapor pressure" is 11.6 lb. and the mercury column reads 11.8 lb. when the gage reading is 11.6 lb. the "gage correction" is plus 0.2 lb. If the "initial air temperature" is 82 F. the correction (see Table I, Column 2) for air temperature is minus 0.9 lb. for Reid-vapor-pressure determinations at an atmospheric pressure of 745 mm. The combined correction is minus 0.7 lb. The "Reid vapor pressure" is 11.6 lb. minus 0.7 lb., or 10.9 lb.

(*b*) Because of the fact that the atmospheric pressure provided (Section 17 (*e*)) for in the air chamber counteracts the external atmospheric pressure, the only pressure acting internally on the pressure gage is the absolute vapor pressure of the liquid in the bomb so that the gage reading is the absolute vapor pressure of the liquid in pounds per square inch at 100 F. (37.8 C.). For purposes of brevity the "Reid vapor pressure" shall be recorded in pounds, without reference to temperature used in the test or to unit of surface.

REPRODUCIBILITY OF RESULTS

Reproducibility of Results

20. With care and strict attention to detail, duplicate tests for vapor pressure should not differ from each other by more than 0.2 lb. plus 1.0 per cent of the vapor pressure as determined.

SAMPLING PROCEDURE FOR PRODUCTS HAVING VAPOR PRESSURES OVER 26 LB.

The special sampling procedure described in the following Sections 21 and 22 is required because the evaporation losses inherent in the sampling procedure described in Sections 11 to 15, inclusive, affect the results substantially if applied to products having vapor pressures much above 26 lb., particularly if these products contain small proportions of very volatile components.

The complete method for products under this title comprises Sections 1 to 3, 5 to 7, 10, 21, 22, 13, and 16 to 20, in the order listed.

21. (*a*) The sample shall be obtained as described in one of the following Paragraphs (*b*), (*c*) or (*d*). This operation fits between the steps described in Section 17 (*d*) and (*e*).

(*b*) *Sampling Directly into Gasoline*

Chamber by Immersion.—The empty gasoline chamber shall first be immersed in the tank or container of the liquid to be tested and allowed to fill while being raised and lowered through the liquid. This operation shall be repeated. These first two fillings are for the purpose of thoroughly washing and chilling the chamber, which shall then be emptied. The chamber shall then be refilled in the same manner, care being exercised to see that it is completely filled with the liquid.

(*c*) *Sampling Directly into Gasoline Chamber from Closed Vessels.*—The gasoline chamber equipped with valves, top and bottom (Fig. 1 (*b*)) shall be used. Before drawing the sample, the gasoline chamber shall be cooled to a temperature as low as or lower than that of the gasoline to be tested. The sample shall be taken as follows: Both valves shall first be closed and the gasoline chamber shall then be connected to the tank, pipe line, or other receptacle holding the liquid to be tested, by means of the lower valve of the chamber. The sample shall be taken at a place which will insure the obtaining of a representative sample of the product to be tested. With the upper valve closed, the valve on the container, tank or pipe line shall be opened and then the lower valve on the gasoline chamber shall be opened, allowing the full tank or line pressure to be exerted on the chamber. The upper valve on the chamber shall then be opened slightly and gasoline allowed to escape until a volume equal to at least twice the capacity of the gasoline chamber shall have been displaced. This procedure will insure the removal of all air from the chamber. Care shall be taken during the operations of purging and filling to prevent more than a slight drop in pressure between the chamber and the tank or line. After filling the gasoline chamber, both the top and bottom valves shall be closed in the order mentioned, and the chamber disconnected from the tank or pipe line (see Section 22).

(*d*) *Sampling into Closed-Type Sample Containers.*—Under conditions which render sampling directly into the gasoline chamber hazardous, the procedure outlined in Section 12 (*b*) shall be used, so that the sample may be kept until ready for testing. When ready to test, the closed-type sample container may be considered as a closed vessel and the sample obtained from it as prescribed in Paragraph (*c*) using water displacement to force the sample into the gasoline chamber and to maintain a pressure substantially in excess of the pressure in the tank at the time of sampling.

Care of Samples

22. If samples are obtained in gasoline chambers of the type illustrated in Fig. 1 (*b*) and the air chamber is not immediately attached, both of the valves on the gasoline chamber shall be closed and plugged and the plugged gasoline chamber shall be kept chilled to a temperature lower than the temperature of the material sampled until the air chamber is attached (Section 17 (*e*)).

Tentative Methods of Test for
KINEMATIC VISCOSITY[1]

A.S.T.M. Designation: D 445 – 38 T

ISSUED, 1937; REVISED, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These methods are suitable for determining the kinematic viscosity of any petroleum product or lubricant which is a true viscous liquid at the temperature of the test.[2] Two procedures are included covering the use of the suspended-level viscosimeter and the modified Ostwald viscosimeter, respectively.

Method A.—Suspended-Level Viscosimeter[3]

Apparatus

2. The apparatus shall consist of one or more calibrated suspended-level viscosimeters, thermometers, bath, and timer conforming to the requirements specified in the following Paragraphs (*a*) to (*d*):

(*a*) *Suspended-Level Viscosimeters.*—The suspended-level viscosimeters (illustrated in Fig. 1 (*a*), (*b*) and (*c*) shall be of glass and shall conform to the requirements in Table I. Instruments with one capillary are shown in Fig. 1 (*a*) and (*b*). In Fig. 1 (*c*) is shown an alternative form of viscosimeter in which two capillaries of different sizes are mounted in the same apparatus, which in effect increases the range available in a given bath.

All suspended-level viscosimeters shall be used only at efflux times greater than 80 sec. There is no upper limit for the efflux time but, in order to save time, it is suggested that a viscosimeter be selected for which the efflux time will be less than 1000 sec. Capillary diameter is not specified in Table I since it depends on the range of viscosities to be measured. For light oils it is necessary to use viscosimeters with smaller capillary diameters than for heavier oils. For viscosity ranges normally encountered, there are given in Table II suggested requirements for capillary diameters and calibration constants for five suspended-level viscosimeters (Note). Viscosimeter No. 1 is suitable for testing low-viscosity products such as kerosines and light fuel oils. The viscosimeters with larger capillary diameters (viscosimeters

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] These methods were developed in response to a need for a more scientific and accurate method for determining viscosity than by means of the Saybolt viscosimeter. Preliminary experiments indicate that the suspended-level and modified Ostwald viscosimeters are subject to much smaller error than the Saybolt instrument. In addition, they measure kinematic viscosity and, therefore, the results are more directly translatable into friction, power requirement and heat development in bearings and other lubricated surfaces. Other forms of apparatus for determining kinematic viscosity are under consideration and may be added later.

[3] For further details of this method, reference should be made to the following articles:

Ogden FitzSimons, "A Rapid Precision Viscosimeter," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 7, p. 345 (1935).

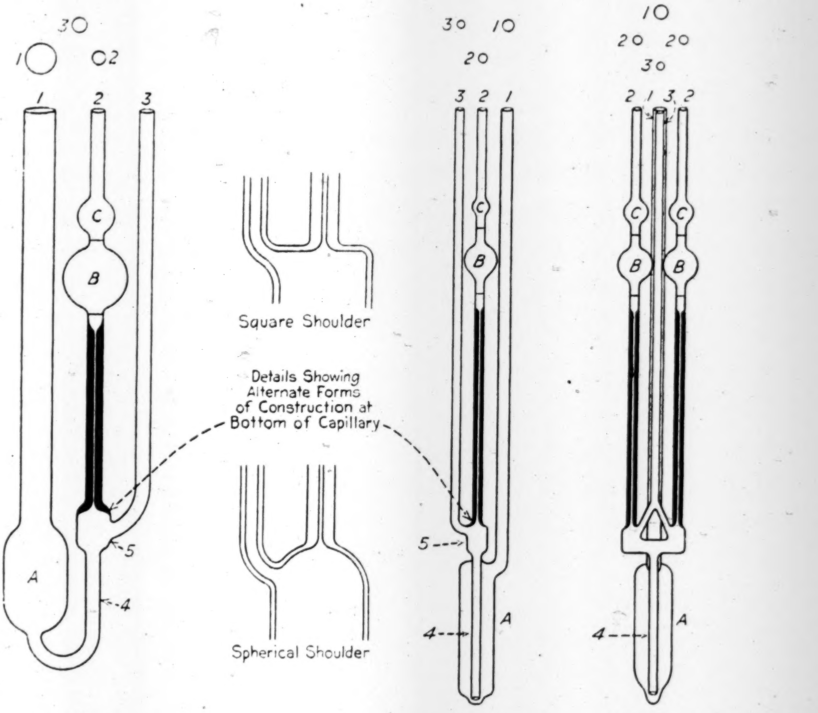
L. Ubbelohde, "The Simplest and Most Accurate Viscometer and Other Instruments with Suspended Level," *Journal*, Inst. Petroleum Technologists (London), Vol. 19, p. 376 (1933); also *Oel und Kohle*, Vol. 12, p. 949 (1936).

L. Ubbelohde, "The Suspended Level Viscometer," *Journal*, Inst. Petroleum Technologists (London), Vol. 22, p. 37 (1936).

L. Ubbelohde, "Viscosimeter," U. S. Patent No. 2048305, July 21, 1936.

L. Ubbelohde, "The Principle of the Suspended Level Applications to the Measurement of Viscosity," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 9, p. 85 (1937).

L. Ubbelohde, "The Viscometer with Suspended Level (The Elimination of the Influence of Surface Tension by the Suspended Spheric Level)," *Journal*, Inst. Petroleum Technologists (London), Vol. 23, No. 165, p. 427 (1937).



(*a*) Ubbelohde Viscosimeter with One Capillary Tube.

(*b*) FitzSimons' Modification with One Capillary Tube.

(*c*) FitzSimons' Modification with Two Capillary Tubes.

FIG. 1.—Suspended-Level Viscosimeters.

TABLE I.—DIMENSIONS OF SUSPENDED-LEVEL VISCOSIMETERS.

		UBBELOHDE VISCOSIMETER	FITZSIMONS' MODIFICATION
Over-all length, mm		260 to 290	300 to 400
Length of capillary, mm		85 to 95	115 to 125
Length from center of bulb *B* to bottom of capillary, mm		125 to 135	140 to 150
Volume between marks, ml		5.4 to 5.8	3.60 to 3.90
Outside diameter	of bulb *C*, mm	10 to 14	10 to 15
	of bulb *A*, mm	20 to 30	20 to 30
Length of bulb *A*, mm		40 to 50	70 to 95
Inside diameter	of tubes 1 and 4, mm	8 to 10	8 to 12
	of tubes 2 and 3, mm	3 to 5	4 to 6
	of tube 5 (square shoulder), mm	10 to 15	10 to 15
	of tube 5 (spherical shoulder), mm	17 to 20	14 to 17

Nos. 1A to 5) cover the ranges of viscosities usually encountered with lubricating oils. It should be noted that the sizes shown in Table II are not mandatory; other capillary diameters may be used, provided the efflux time is greater than 80 sec.

NOTE.—In case the amount of testing does not warrant installation of five suspended-level viscosimeters it is possible, with equal accuracy, to make use of longer times of outflow, thereby eliminating one or more. For instance, in the case of the FitzSimons' modification, viscosimeter No. 2 may serve for viscosities varying from 3.0 to 30 centistokes and No. 4 from 20 to 1200 centistokes, thus making it unnecessary to install viscosimeters Nos. 3 and 5. A corresponding selection of instruments may also be made in the case of the Ubbelohde viscosimeter.

TOTAL LENGTH: 235 to 241 mm. (9.25 to 9.48 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.5 to 7.5 mm. (0.256 to 0.295 in.).

BULB: Corning normal or equally suitable thermometer glass.

Length, 45 to 55 mm. (1.77 to 2.17 in.).

Diameter, 6 mm. (0.236 in.) to not greater than stem.

ICE POINT: Graduated 31.5 to 32.5 F. in 0.1 F. division; 32 F. to be 80 to 85 mm. (3.15 to 3.35 in.) from bottom of bulb.

CONTRACTION CHAMBER: To be long narrow type, bottom not less than 100 mm. (3.94 in.) from bottom of bulb; top to be not more than 125 mm. (4.95 in.) from bottom of bulb.

DISTANCE TO LOWEST SPECIFIED GRADUATION FROM BOTTOM OF BULB: 140 to 155 mm. (5.51 to 6.10 in.).

TABLE II.—SUGGESTED CAPILLARY DIAMETERS OF SUSPENDED-LEVEL VISCOSIMETERS WITH CORRESPONDING VISCOSITY RANGES AND CALIBRATION CONSTANTS.

Suspended-Level Viscosimeter	Efflux Time, sec.	Ubbelohde Viscosimeter				FitzSimons' Modification			
		Capillary Diameter, mm.	Approximate Calibration Constant, C[a]	Approximate Viscosity Range		Capillary Diameter, mm.	Approximate Calibration Constant, C[a]	Approximate Viscosity Range	
				Centistokes	Saybolt Universal Seconds			Centistokes	Saybolt Universal Seconds
No. 1	80 to 1000	0.61 to 0.65	0.01	1 to 10	Up to 58	0.42 to 0.44	0.003	0.5 to 6.5	Up to 47
No. 1A	80 to 1000	0.92 to 0.98	0.05	4 to 50	40 to 230	....	.....	....	......
No. 2	80 to 1000	1.10 to 1.16	0.10	8 to 100	50 to 460	0.78 to 0.84	0.035	3.0 to 30	36 to 140
No. 3	80 to 1000	1.96 to 2.04	1.0	80 to 1000	370 to 4600	1.02 to 1.08	0.10	9 to 100	55 to 460
No. 4	80 to 1000	3.50 to 3.65	10.0	800 to 10 000	3700 to 46 000	1.28 to 1.36	0.25	20 to 250	100 to 1150
No. 5	80 to 1000	....	.....	....	....	1.92 to 2.00	1.2	100 to 1200	460 to 5500

[a] The correct calibration constant depends on the actual dimensions of the instruments and therefore must be determined by experiment. The values in the above table are intended to serve as a guide only.

(*b*) The A.S.T.M. Kinematic Viscosity Test Thermometer shall conform to the following requirements. These specifications cover three total-immersion thermometers graduated in Fahrenheit degrees the ranges, as specified, being 97.5 to 102.5 F.; 127.5 to 132.5 F.; and 207.5 to 212.5 F., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISIONS:

Temperature Range	Subdivisions	For Tests at
97.5 to 102.5 F.	0.1 F.	100 F.
127.5 to 132.5 F.	0.1 F.	130 F.
207.5 to 212.5 F.	0.1 F.	210 F.

DISTANCE TO HIGHEST SPECIFIED GRADUATION FROM TOP OF THERMOMETER: 25 to 40 mm. (0.98 to 1.57 in.).

EXPANSION CHAMBER: To permit heating to 220 F.

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATIONS: All lines and figures clear cut and distinct. The first and each succeeding 0.5 F. line to be longer than the remaining lines. Graduations to be numbered at each 1 F.

IMMERSION: Total.

SPECIAL MARKINGS: "A.S.T.M. Kin. Vis.," a serial number and manufacturer's name or trade-mark shall be etched on the stem.

SCALE ERROR: The error at the viscosity point (100, 130, or 210 F.) not to exceed 0.10 F.

STANDARDIZATION: The thermometers are to be standardized at the ice point, and at the viscosity point (100, 130, or 210 F.) for conditions of total immersion, expressed to the nearest 0.02 F. and such corrections are to be added to the observed reading.

CASE: Each thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Kinematic Viscosity Thermometer," and the range.

NOTE.—For the purpose of interpreting these specifications the following descriptions of terms apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

(*c*) *Bath.*—A bath suitable for immersion of the viscosimeter to within 5 cm. of the top, with provision for visibility of the instrument and the thermometer, shall be provided. The viscosimeter may be sealed in as an integral part of the bath. The thermometer shall be mounted with the bulb near the center of the viscosimeter. The bath shall be regulated so that the variation in the thermometer reading does not exceed 0.05 F. (0.03 C.). Either a liquid bath with thermostatic regulation and stirrer or a vapor bath with pressure regulation is permissible, the following materials being satisfactory for the purpose indicated:

Bath Temperature	Liquid Bath	Vapor Bath
100 F. (37.78 C.)	Water	Methylene chloride
210 F. (98.89 C.)	White oil Ethylene glycol	Tertiary amyl alcohol

(*d*) *Timer.*—The stop watch or other timing device used shall be graduated in divisions of 0.2 sec. or less, and shall be accurate to within 0.1 per cent when tested over a 60-min. period (Note).

NOTE.—Electrical timing devices are permissible provided they are accurate and capable of being read to 0.2 sec. Timing devices actuated by synchronous motors shall be used only on electric circuits of controlled frequency.

Procedure

3. (*a*) The proper suspended-level viscosimeter, according to Table II, shall be selected. The viscosimeter shall be cleaned by rinsing twice with petroleum ether, benzol, or a narrow cut of naphtha. This solvent shall then be removed by passing a current of clean, dry air through the viscosimeter and for this reason the solvent used shall be of such volatility that it will be easily and completely removed under these conditions.

NOTE 1.—The viscosimeter may be left in place in the bath, in which case the oil from the previous determination shall be withdrawn by suction through tube 3, after which portions of naphtha shall be successively introduced into tube 1, drawn up into tube 2 several times and removed by suction through tube 3. The tubes shall then be dried of naphtha by passing air through them.

NOTE 2.—Periodically, or whenever the appearance of the viscosimeter indicates the need of it, the instrument shall be cleaned by use of chromic acid which shall be allowed to stand in the tube for several hours, followed by thorough rinsing first with distilled water, then with c.p. acetone and drying by air current.

(*b*) The viscosimeter shall be immersed in the bath so that bulb *C* is below the surface of the bath liquid and shall be adjusted to a vertical position. This may be accomplished by visual examination in two different vertical planes or by employing a small plumb bob consisting of a 1-cm. length of solder wire and a piece of silk thread attached to a perforated cork placed in the wide arm of the instrument. When properly aligned, the plumb bob will not touch the walls.

(*c*) A small sample of oil (about 10 ml.) shall be filtered through a fritted (sintered) glass filter of medium porosity or a 100-mesh screen filter into a small beaker or bottle. The oil sample as well as the viscosimeter must be free from any solid particles, lint, etc. The oil sample shall be charged into tube 1 of the viscosimeter.

(*d*) The bath shall be maintained at the temperature of test within plus or minus 0.025 F. The viscosimeter shall remain in the constant-temperature bath long enough to reach the bath temperature. The minimum time required is 5 min. for the 100 F. (37.78 C.) bath, and 10 min. for the 210 F. (98.89 C.) bath.

(*e*) After the sample has attained bath temperature, tube 3 shall be stoppered with the finger and the oil shall be drawn into tube 2 by suction to some point above the upper mark but not above the center of the small bulb. (When using the double instrument, the tube 2 not being used must be closed as well as tube 3.)

(*f*) The suction shall then be released and the finger removed from tube 3, allowing the oil to flow freely out of the capillary tube. The time in seconds required for the meniscus to pass from the upper to the lower mark shall be measured. If this efflux time is less than 80 sec., the next smaller viscosimeter shall be selected and the operation repeated. Determinations shall be repeated until two successive efflux times agree within 0.2 per cent, the average of these two determinations being used for calculating the kinematic viscosity.

Reporting Results

4. The kinematic viscosity in centistokes shall be calculated from the following equation:

$$V = Ct - \frac{B}{t} \quad \ldots\ldots\ldots (1)$$

where V = the kinematic viscosity in centistokes,

C = the determined calibration constant for the instrument,

t = the efflux time in seconds, and

B = an experimental constant determined by the design of viscosimeter. For viscosimeters with capillary diameters of 0.75 mm. or larger, the value of this constant is 2.8 for the Ubbelohde design and 1.0 for the FitzSimons' design; in the case of viscosimeters having capillary diameters less than 0.75 mm., the value of the constant shall be determined in accordance with Section 5 (*b*).

NOTE.—For routine use a tabulation in which the kinematic viscosity is shown for integral efflux times over the range used shall be prepared for each instrument based on Eq. (1) and on the calibration constant for the instrument. Interpolation tables should also be shown.

Calibration

5. The suspended-level viscosimeters shall be calibrated in accordance with one of the methods described in the following Paragraphs (*a*) and (*b*). The calibration constant determined at 100 F. (37.78 C.) shall be valid for use at other temperatures also.

(*a*) *For Viscosimeter with Capillary Diameter 0.75 mm. or Larger.*—The efflux time of an oil standard obtained from the American Petroleum Institute or National Bureau of Standards may be determined in the viscosimeter being calibrated. The efflux time for the oil standard shall be not less than 150 sec. The calibration constant, C, may then be calculated by substituting in Eq. (1) this efflux time and the kinematic viscosity of the oil standard and solving for the value of C.

An alternative procedure is to determine with the viscosimeter being calibrated the efflux time of an oil sample whose viscosity has been previously determined in a viscosimeter calibrated in accordance with Paragraph (*b*), or in a viscosimeter calibrated with a reference oil, or in a large viscosimeter calibrated as outlined in the reference appearing in the footnote to the title of Method B. The calibration constant, C, may then be calculated by substituting in Eq. (1) this efflux time and the kinematic viscosity of the oil sample.

(*b*) *For Viscosimeter with Capillary Diameter Less than 0.75 mm.*—The constants B and C in Eq. (1) shall be determined for each viscosimeter, as follows: The efflux times of pure distilled water shall be determined at 68 F. (20 C.), 100 F. (37.78 C.), and 130 F. (54.44 C.), in the viscosimeter being calibrated. The temperature shall be maintained within plus or minus 0.02 F. (0.01 C.) of the desired test temperature. The kinematic viscosity of water shall be taken as 1.007 centistokes at 68 F. (20C.)., 0.689 centistokes at 100 F. (37.78C.), and 0.518 centistokes at 130 F. (54.44 C.). The constants B and C_w (water) shall be the average of the three results calculated for each pair of temperatures from the following equations:

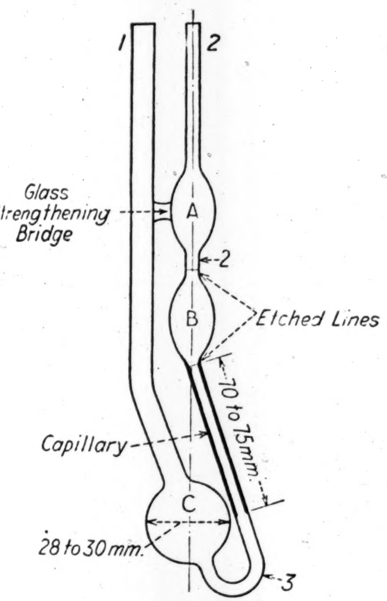


FIG. 2.—Modified Ostwald Viscosimeter.

$$B = \frac{t_1 t_2}{t_2^2 - t_1^2} (V_2 t_1 - V_1 t_2)$$

$$C_w = \frac{V_2 t_2 - V_1 t_1}{t_2^2 - t_1^2}$$

where B = the experimental constant determined by the design of the instrument,

C_w = the calibration constant determined with water as the calibrating liquid,

V_1 = the kinematic viscosity of water giving an efflux time of t_1, and

V_2 = the kinematic viscosity of water giving an efflux time of t_2.

TABLE III.—DIMENSIONS OF MODIFIED OSTWALD VISCOSIMETERS.

Over-all length, mm		240 to 260
Length of capillary, mm		70 to 75
Volume of bulbs *A* and *B*, each, ml		3.0 to 3.3
Distance from center of bulb *B* to center of bulb *C*, mm		85 to 95
Inside diameter	of bulb *C*, mm	28 to 30
	of tube 1, mm	8 to 12
	of tube 2, mm	1.5 to 2.5
	of tube 3, mm	3 to 5

The mean effective head does not affect the kinetic energy correction and accordingly, constant B is the same for all liquids. In the case of the viscosimeter with square-shouldered outlet tube, the mean effective head varies with liquids of different surface tension. It is accordingly necessary to compensate for the marked difference in surface tension of water and oil by multiplying C_w by 1.0035. This latter value is determined from the surface tensions of water and oil and is also based on the design of the instrument. The equation of the viscosimeter calibrated with water becomes as follows when used with petroleum fractions:

$$V = 1.0035\, C_u t - \frac{B}{t}$$

If a viscosimeter with a spherical shoulder is used, the head does not vary with surface tension; therefore, the multiplying constant is 1.000 instead of 1.0035.

Method B.—Modified Ostwald Viscosimeter[4]

Apparatus

6. The apparatus shall consist of one or more calibrated modified Ostwald viscosimeters, thermometers, bath, and timer conforming to the requirements specified in the following Paragraphs (*a*) to (*d*):

(*a*) *Modified Ostwald Viscosimeters.*—The modified Ostwald viscosimeters (illustrated in Fig. 2) shall be of glass and shall conform to the dimensional requirements prescribed in Table III.

Each modified Ostwald viscosimeter shall be so constructed that a line drawn vertically through the center of bulbs *A* and *B* will pass through the center of bulb *C* (Fig. 2). Capillary diameter is not specified in Table III, since it depends on the range of the viscosity to be measured. For light oils it is necessary to use viscosimeters with smaller capillary diameters than for heavier oils. For the viscosity range normally encountered, there are given in Table IV suggested requirements for capillary diameters for four modified Ostwald viscosimeters (Note). It should be noted that the sizes shown in Table IV are not mandatory; other capillary diameters may be used provided the time of efflux is greater than 300 sec. for viscosimeters with capillary diameters less than 0.50 mm., 200 sec. for capillary diameters between 0.50 and 0.75 mm., and 100 sec. for capillary diameters greater than 0.75 mm.

TABLE IV.—SUGGESTED CAPILLARY DIAMETERS OF MODIFIED OSTWALD VISCOSIMETERS WITH CORRESPONDING VISCOSITY RANGES.

Modified Ostwald Viscosimeter	Efflux Time, sec.	Capillary Diameter, mm.	Approximate Viscosity Range	
			Centistokes	Saybolt Universal Seconds
No. 50	300 to 1500	0.40 to 0.45	0.8 to 3	....
No. 100	200 to 700	0.60 to 0.65	3 to 10	35 to 65
No. 200	100 to 700	0.97 to 1.03	10 to 70	60 to 325
No. 300	100 to 700	1.20 to 1.30	25 to 175	120 to 800
No. 400	100 to 700	1.80 to 1.90	120 to 850	550 to 4000
No. 500	100 to 700	2.70 to 2.90	800 to 5600	3600 to 25 000

NOTE.—In case the amount of testing does not warrant installation of four modified Ostwald viscosimeters it is possible, with equal accuracy, to make use of longer times of outflow, thereby eliminating one or more. For instance, viscosimeter No. 100 may serve for viscosities varying from 3 to 25 centistokes and No. 300 for viscosities from 25 to 850 centistokes, thus making it unnecessary to install viscosimeters Nos. 200 and 400.

(*b*) *Thermometers.*—As described in Section 2 (*b*).

(*c*) *Bath.*—As described in Section 2 (*c*).

(*d*) *Timer.*—As described in Section 2 (*d*).

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[4] For further details of this method, reference should be made to "Viscosity Standardization of Petroleum Lubricating Fractions" by M. R. Cannon and M. R. Fenske, *Oil and Gas Journal,* Vol. 33, p. 52, April 11, 1935; and "Simple Viscometers and Auxiliary Equipment for the Accurate Measurement of Viscosity in Fundamental Units" by M. R. Cannon and M. R. Fenske, *Oil and Gas Journal,* Vol. 34, p. 45, April 9, 1936

Procedure

7. (*a*) The proper modified Ostwald viscosimeter, according to Table IV, shall be selected. The viscosimeter shall be cleaned by rinsing twice with petroleum ether, benzol, or a narrow cut of naphtha. This solvent shall then be removed by passing a current of air through the viscosimeter and for this reason the solvent used must be of such volatility that it will be easily and completely removed under these conditions.

(*b*) A small sample of oil (about 10 ml.) shall be filtered through a fritted (sintered) glass filter of medium porosity or a 100-mesh screen filter into a small beaker or bottle. The oil sample as well as the viscosimeter must be free from any solid particles, lint, etc.

(*c*) The oil at a temperature of 70 to 90 F. (21.11 to 32.22 C.) shall be charged into the viscosimeter in the following manner: The instrument shall be held in an inverted vertical position with the end of the capillary arm immersed in the oil. Both bulbs on the capillary side of the viscosimeter shall be filled with oil by suction, and the oil brought into the working capillary up to the mark etched on it. Care shall be used that the rubber tubing employed in applying the suction shall be clean.

(*d*) After loading, the excess oil shall be wiped off the top of the viscosimeter and it shall then be placed in the constant temperature bath. It shall be immersed so that bulb *A* is below the surface of the bath liquid.

NOTE.—A convenient way to support the viscosimeter in the bath is to clamp a rubber stopper on the instrument and to provide the cover of the constant-temperature bath with holes to receive the rubber stopper. A No. 10 rubber stopper with a 1.0-cm. hole and with a section 0.5 cm. in width cut out from the opening to the side of the stopper is suggested.

(*e*) The viscosimeter shall be adjusted to a vertical position. This may be accomplished by visual examination in two different vertical planes or by employing a small plumb bob consisting of a 1-cm. length of solder wire and a piece of silk thread attached to a perforated cork placed in the wide arm of the instrument. When properly aligned the plumb bob will not touch the walls.

(*f*) The viscosimeter shall remain in the constant-temperature bath long enough to reach the bath temperature. The minimum time required is 5 min. for the 100 F. (37.78 C.) bath, and 10 min. for the 210 F. (98.89 C.) bath.

(*g*) During the heating stage the oil will drain from the upper bulbs into the lower reservoir and in the course of this operation a bubble of air may be trapped in the bend at the bottom of the instrument. When the oil level is brought to the etched line between the bulbs this air shall be removed, so that there will be an unbroken column of oil extending from the lower reservoir through the capillary during the test.

(*h*) After the sample has attained bath temperature, suction shall be applied to the capillary arm to draw the oil sample up to a point about 5 mm. above the mark between the bulbs. The suction shall then be released thereby opening this arm to the atmosphere. The time for the meniscus to pass from the upper to the lower mark shall be measured.

(*i*) The viscosity of the oil in centistokes shall then be obtained by multiplying the efflux time by the viscosimeter constant.

(*j*) A check determination shall be made by again drawing the oil sample above the etched line between the bulbs and timing as before. In careful work it may be desirable to run the same oil in two different viscosimeters.

NOTE.—An experienced operator can run six or more viscosimeters at one time. During the preheating stage of one viscosimeter, another instrument may be loaded or cleaned so that no time is lost. Small (10-in. diameter) constant-temperature baths will hold six or more viscosimeters.

Reporting Results

8. The kinematic viscosity in centistokes shall be calculated from the following equation:

$$V = Ct \qquad (2)$$

where V = the kinematic viscosity in centistokes,

C = the determined calibration constant for the instrument, and

t = the efflux time in seconds.

Calibration

9. The modified Ostwald viscosimeters shall be calibrated in accordance with one of the methods described in the following Paragraphs (*a*) and (*b*):

(*a*) The outflow time of an oil standard obtained from the American Petroleum Institute or National Bureau of Standards may be determined in the viscosimeter being calibrated. The efflux time for the oil standard shall be not less than 150 sec. The calibration constant C, may then be calculated by substituting in Eq. (2) this efflux time and the kinematic viscosity of the oil standard and solving for the value of C.

(*b*) An alternative procedure is to determine the calibration constant C by means of a master viscosimeter or calibrated instrument of the type as outlined in the reference appearing in the footnote to the title of Method B.

(*c*) If it is desired to perform all calibrations at 100 F. (37.78 C.) the calibration constants at 60 F. (15.56 C.), 130 F. (54.44 C.), and 210 F. (98.89 C.) may be obtained from Equations (1), (2) and (3).[5]

Calibration constant at 210 F. (98.89 C.) = 0.996 × calibration constant at 100 F. (37.78 C.)..(1)

Calibration constant at 130 F. (54.44 C.) = 0.999 × calibration constant at 100 F. (37.78 C.)..(2)

Calibration constant at 60 F. (15.56 C.) = 1.001 × calibration constant at 100 F. (37.78 C.)..(3)

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[5] A more general equation which expresses the change in the calibration constant of the modified Ostwald viscosimeter with variation in temperature is as follows:

$$T_2 = C_{T_1}\left[1 - \frac{\text{Vol.}_2 - \text{Vol.}_1}{0.785\, H\, d^2}\right]$$

where C_{T_2} = the calibration constant at T_2, the temperature for which the constant is being calculated,

C_{T_1} = the calibration constant at T_1, the temperature at which the constant is known,

Vol._2 = the total volume of liquid in the viscosimeter at T_2,

Vol._1 = the total volume of liquid in the viscosimeter at T_1,

H = the fluid head; for viscosimeters shown in Fig. 2, this is approximately 90 mm., and

d = the inside diameter of the lower reservoir; for viscosimeters shown in Fig. 2, this is approximately 30 mm.

TENTATIVE METHOD OF TEST FOR TAR ACIDS IN CREOSOTE AND CREOSOTE-COAL TAR SOLUTIONS[1]

A.S.T.M. Designation: D 453 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. This method is intended for determining the amount of tar acids in the fractions distilled from creosote and creosote - coal tar solutions.

Apparatus

2. (*a*) *Type I, Separatory Funnel.*—The Type **I** glass separatory funnel shall conform to the requirements shown in Fig. 1 (*a*). It shall have a total capacity of approximately 200 ml. with the lower 20 ml. graduated accurately in 0.1 ml. The graduation marks shall be numbered for each milliliter.

(*b*) *Type II, Separatory Funnel.*—The Type II glass separatory funnel shall have a total capacity of approximately 260 ml. and shall conform to the requirements shown in Fig. 1 (*b*). The capacity of the lower bulb from the stopcock to the first graduation mark shall be 65 ml., and above this mark the stem shall be graduated accurately for 100 ml. in 0.2 ml. The graduation marks shall be numbered for each milliliter.

Procedure

3. (*a*) In making the determination, 100 g. of the sample shall be distilled in accordance with the Standard Method of Test for Distillation of Creosote (A.S.T.M. Designation: D 246) of the American Society for Testing Materials.[2] The fraction (Note) to be tested shall be transferred to a regular 250-ml. glass-stoppered separatory funnel, and 50 ml. of c.p. benzol and 50 ml. of an 18.3 per cent solution of NaOH (sp. gr. 1.20 at 20/40 C.) shall be added. The mixture shall be shaken vigorously for 3 min. and allowed to settle. The well-settled lower portion of the liquid shall then be drawn off into a 250-ml. beaker. An additional 30 ml. of the NaOH solution (18.3 per cent) shall be added to the separatory funnel and

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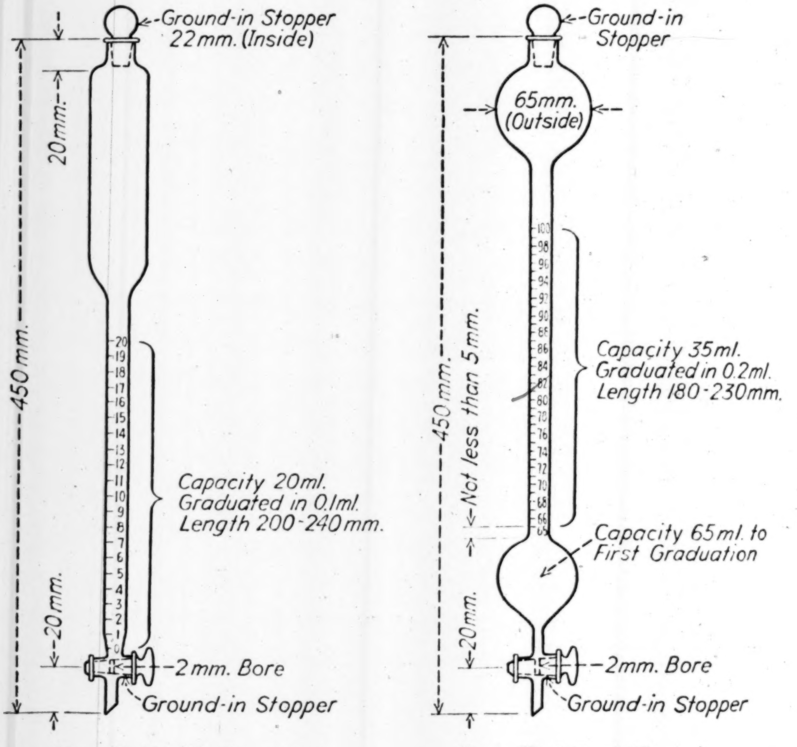
[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-7 on Timber.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 542.

the contents gently shaken for 2 min. After settling, the lower portion of the liquid shall be drawn off and added to the beaker containing the first portion. Sufficient diluted H_2SO_4 (1:3) shall be added to the mixture in the beaker to turn blue litmus paper definitely red. The solution shall be cooled during the addition of the acid.

(*b*) If the tar acids liberated are estimated to be under 10 ml., Type I separatory funnel (Section 2 (*a*)) shall be used and 10 ml. of "Hi-flash" naphtha or c.p. benzol at 25 C. shall be measured into it. The liberated tar acids and sulfate solution shall then be poured through this layer of naphtha or benzol several times, drawing the material off at the bottom of the funnel into the original beaker and pouring it back into the top of the funnel. This washes out the beaker and allows all the tar acids to be absorbed. The funnel shall then be allowed to stand at 25 C., until the layers separate clearly, when the sulfate solution shall be drawn off and the increase in the volume of the naphtha or benzol taken as the dry tar acids present.



Ground-in Stopper 22 mm. (Inside)
20 mm.
450 mm.
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Capacity 20 ml. Graduated in 0.1 ml. Length 200-240 mm.
20 mm.
2 mm. Bore
Ground-in Stopper
Ground-in Stopper
65 mm. (Outside)
100 98 96 94 92 90 88 86 84 82 80 78 76 74 72 70 68 66 65
Capacity 35 ml. Graduated in 0.2 ml. Length 180-230 mm.
450 mm.
Not less than 5 mm.
Capacity 65 ml. to First Graduation
20 mm.
2 mm. Bore
Ground-in Stopper

Type I, 200-ml. Capacity. Type II, 260-ml. Capacity.

FIG. 1.—Glass Separatory Funnels for Tar Acid Test of Creosote.

(*c*) If the tar acids liberated are estimated to be more than 10 ml., the procedure described in Paragraph (*b*) shall be followed except that 65 ml. of "Hi-flash" naphtha or c.p. benzol at 25 C. shall be measured into the Type II separatory funnel (Section 2 (*b*)).

NOTE.—If the total content of tar acids in a sample is desired, the entire distillate below 355 C. should be tested. In this case the results shall be reported as percentage by volume, that is, as the number of milliliters of tar acids per 100 ml. of the original dry sample, both volumes measured at the same temperature.

Calculation

4. The amount of tar acids shall be reported as a percentage of the fraction tested, calculated as follows:

$$\text{Percentage of tar acids} = \frac{\text{Volume of tar acids in milliliters}}{\text{Weight of fraction in grams}} \times 100$$

In the above formula, the assumption is made that 1 ml. of tar acids weighs 1 g.

Tentative Method of
SAMPLING COALS CLASSED ACCORDING TO ASH CONTENT[1]

A.S.T.M. Designation: D 492 - 38 T

ISSUED, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. (*a*) This method is applicable for the sampling of coal as sold, classified in accordance with the ash content. It is stated in terms of a minimum number of increments to be taken in each case, of a minimum weight, resulting in a specified minimum weight of gross sample.

(*b*) Two distinct procedures are recognized in this method, as follows:

Commercial Sampling Procedure
Special Purpose Sampling Procedure

(*c*) This method does not cover the sampling of resultant coals with top size over 2 in. or for sized coal over 6 in., as present data and experience on which to base a method for these grades are considered inadequate at this time.

Commercial Sampling

2. (*a*) The "commercial" procedure prescribed in Table I shall apply to average commercial sampling of coal and is designed so that 95 per cent of the test results fall within plus or minus 10 per cent of the ash content of the coal sampled.

(*b*) Under the "commercial" procedure for lots up to 1000 tons, it is recommended that one gross sample be taken in accordance with the requirements in Table I to represent the lot. Where a larger tonnage is to be sampled, either of the alternatives may be used:

(*1*) Separate gross samples may be taken for each 1000 tons, or fraction thereof, and an average of the prepared samples from these portions used to represent the lot.

(*2*) One gross sample may be used to represent the lot, provided that the minimum number of increments specified in Section 3 be taken.

Special Purpose Sampling

3. The "special purpose" procedure shall apply to the sampling of coal where special accuracy is required, such as classification by grade or rank,[2] or performance test work. The minimum number of increments taken for coals sampled by this procedure shall conform to the requirements in Table I, which specifies five times the minimum number required under the "commercial" procedure.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-5 on Coal and Coke.

[2] Standard Specifications for Classification of Coals by Rank (A.S.T.M. Designation: D 388) and Standard Specifications for Classification of Coals by Grade (A.S.T.M. Designation: D 389), see 1937 and 1938 Supplements to Book of A.S.T.M. Standards.

Increments

4. (*a*) The term "increment" as used herein designates that quantity of coal obtained for the sample by a single motion of the sample instrument, such as swinging it through a stream of coal, or digging into the top of a carload. It is recommended that where possible the coal be sampled while in motion.

(*b*) In every individual case, the method of selecting the increment shall be suited to the existing conditions, and the experience with the variation of those conditions used to govern the procedure. It is well established that variations in flow, structure, size-consist of the coal, or in distribution of impurities may tend to nullify the economic advantages of small increments. The minimum weights of increment specified in this method may be used only when the method of their selection is satisfactorily within the desired limits of accuracy.

(*c*) It is essential that gross samples shall consist of not less than the specified number of increments, each of approximately the same weight, and that the increments be distributed evenly over the lot of coal sampled.

Size Groups

5. Coals to be sampled shall be divided into the following four groups as to size:

	SIZE DESIGNATIONS[a] (ROUND-HOLE SCREENS)	TYPE OF COAL[b]
Group 1	......Top size, ⅝ in., or less	Resultants and sized coals
Group 2	..........Top size, 1¼-⅝ in.	Resultants and sized coals
Group 3	..........Top size, 2-1¼ in.	Resultants and sized coals
Group 4	............Top size, 6-2 in.	Sized coals only

[a] The "top size" dimension indicates all coals with such size-consist as classify them under the group in accordance with Section 4 of the Standard Method of Designating the Size of Coal from Its Screen Analysis (A.S.T.M. Designation: D 431) of the American Society for Testing Materials.[3]

[b] The term "resultant" indicates a commercial grade of coal whose size-consist is essentially produced as a through-product of but one screen.

The term "sized coal" indicates a commercial grade of coal whose size-consist is essentially produced as a material passing through and retained upon two screens, respectively.

TABLE I.—SAMPLING METHOD FOR COALS CLASSED ACCORDING TO ASH CONTENT.

	Less than 8 per cent Ash				8.0 to 9.9 per cent Ash				10.0 to 14.9 per cent Ash				15.0 per cent Ash and Over			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
Top Size[a]..............................	⅝ in. or less	1¼-⅝ in.	2-1¼ in.	6-2 in.	⅝ in. or less	1¼-⅝ in.	2-1¼ in.	6-2 in.	⅝ in. or less	1¼-⅝ in.	2-1¼ in.	6-2 in.	⅝ in. or less	1¼-⅝ in.	2-1¼ in.	6-2 in.
"COMMERCIAL" PROCEDURE																
Minimum number of increments..........	15	15	15	15	20	20	20	20	35	35	35	35	35	35	35	35
Minimum weight of increment, lb.........	2	4	6	10	2	4	6	10	2	4	6	10	2	4	6	10
Minimum weight of gross sample, lb......	30	60	90	150	40	80	120	200	70	140	210	350	70	140	210	350
"SPECIAL PURPOSE" PROCEDURE																
Minimum number of increments..........	75	75	75	75	100	100	100	100	175	175	175	175	175	175	175	175
Minimum weight of increment, lb.........	2	4	6	10	2	4	6	10	2	4	6	10	2	4	6	10
Minimum weight of gross sample, lb......	150	300	450	750	200	400	600	1000	330	700	1050	1750	350	700	1050	1750

[a] Group 1......Top size ⅝ in. or less, round-hole screens; resultants and sized coals.
Group 2......Top size 1¼-⅝ in., round-hole screens; resultants and sized coals.
Group 3......Top size 2-1¼ in., round-hole screens; resultants and sized coals.
Group 4......Top size 6-2 in., round-hold screens; sized coals only.

Reduction of Sample

6. Samples obtained by this method shall be reduced for analysis by mechanical preparation, as follows:

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[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 166.

(*a*) Gross samples of coal containing pieces ⅜ in. and larger shall be crushed before dividing so that at least 95 per cent by weight will pass through a 4760-micron (No. 4) sieve and 100 per cent will pass through a ⅜-in. round-hole screen. Gross samples of coal of which 100 per cent passes through a ⅜-in. round-hole screen and less than 95 per cent by weight passes through a 4760-micron (No. 4) sieve may be divided before crushing to not less than 60 lb. as described in Paragraph (*b*) by means of a riffle sampler or its equivalent.

(*b*) The entire gross sample crushed as described under Paragraph (*a*) shall be reduced in quantity to not less than 30 lb. by passing through a riffle sampler or its equivalent. The riffle sampler shall have openings of not less than ¾ in. and not more than 1 in.

(*c*) The sample of not less than 30 lb., obtained as described under Paragraph (*b*), shall be crushed so that 100 per cent will pass through a 4760-micron (No. 4) sieve, and shall then be divided by passing through a riffle sampler with openings not less than ½ in. and not more than ¾ in., obtaining a sample of not less than 15 lb.

(*d*) The sample of not less than 15 lb., obtained as described under Paragraph (*c*), which has been crushed so that 100 per cent will pass a 4760-micron (No. 4) sieve shall be further crushed so that 95 per cent or more by weight will pass through a 2380-micron (No. 8) sieve. The sample shall then be divided by passing it through a riffle sampler with openings not over ½ in., obtaining a sample of not less than 1¾ lb. by no more than three passes through the riffle.

It is not practical to crush wet coal to pass a 2380-micron (No. 8) sieve. If the sample of not less than 15 lb., which has been crushed to pass a 4760-micron (No. 4) sieve appears wet, it shall be air dried before crushing so that 95 per cent will pass through a 2380-micron (No. 8) sieve. However, if the determination of total moisture is of any significance, the entire sample of not less than 15 lb. of wet coal shall be placed in an air-tight container for transmittal to the laboratory.

(*e*) The riffle samplers specified in Paragraphs (*b*), (*c*), and (*d*) shall be similar in type to those shown in Fig. 2 (*a*) and (*b*) of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials.[4]

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[4] 1937 Supplement to Book of A.S.T.M. Standards, p. 153.

TENTATIVE DEFINITIONS FOR VARIETIES OF BITUMINOUS AND SUBBITUMINOUS COALS[1]

A.S.T.M. Designation: D 493 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

These definitions apply only to commercial varieties of coals.

Common Banded Coal.—The common variety of bituminous and subbituminous coal. It consists of a sequence of irregularly alternating layers or lenses of (*1*) homogeneous black material having a brilliant vitreous luster, (*2*) grayish-black, less brilliant, striated material usually of silky luster, and (*3*) generally thinner bands or lenses of soft, powdery, and fibrous particles of mineral charcoal. The difference in luster of the bands is greater in bituminous than in subbituminous coal.

Splint Coal.—A variety of bituminous or subbituminous coal, commonly having a dull luster and grayish-black color, of compact structure, often containing a few thin irregular bands with vitreous luster. When struck, it is resonant. It is hard and tough and breaks with an irregular, rough, sometimes splintery fracture. It is free burning and does not swell on heating.

Cannel Coal.—A variety of bituminous or subbituminous coal of uniform and compact fine-grained texture with a general absence of banded structure. It is dark gray to black in color, has a greasy luster, and is noticeably of conchoidal or shell-like fracture. It is non-caking, yields a high percentage of volatile matter, ignites easily, and burns with a luminous, smoky flame.

Boghead Coal.—A variety of bituminous or subbituminous coal resembling cannel coal in appearance and behavior during combustion. It is characterized by a high percentage of algal remains and volatile matter. Upon distillation it gives exceptionally high yields of tar and oil.

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[1] Under the standardization procedure of the Society, these definitions are under the jursidiction of the Sectional Committee on Classification of Coals functioning under the procedure of the American Standards Association with the American Society for Testing Materials as sponsor.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT PLANK[1]

A.S.T.M. Designation: D 517 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.[2]

Scope

1. These specifications cover asphalt plank of two types as used for bridge floors:

(*a*) Plain Asphalt Plank, and

(*b*) Mineral-Surfaced Asphalt Plank.

SPECIFICATIONS

Manufacture

2. Asphalt plank shall be a mixture of asphalt, fiber, and mineral aggregate formed by extrusion under sufficient pressure to expel the air and form a dense mass.

Mineral Surfacing

3. In the case of mineral-surfaced asphalt plank, at least 15 oz. per sq. ft. of tough, hard, durable, coarse aggregate (well-graded from No. 4 to $\frac{3}{4}$ in. square-opening sieves) shall be embedded under pressure into one surface of the freshly-extruded hot plank to such a depth that none extends above the intended wearing surface. The top surface of the mineral surfacing shall not be covered with the matrix of the plank proper.

Workmanship

4. The asphalt plank shall be free from defects affecting its serviceability or appearance; it shall have straight edges and square corners.

Asphalt Cement

5. The asphalt cement shall have such characteristics that, when combined with the other ingredients, a plank of desired quality will result.

Fiber

6. The fibrous material shall consist of finely divided whole threads or fiber free from lumps and when used it shall be in a flocculent condition. This fabric and fibrous material shall be free from all foreign materials such as metal, leather, straw, sawdust, cornstalks, or other deleterious materials.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Mineral Filler

7. The mineral filler shall consist of finely crushed slate, limestone, asbestos, silica, or other aggregate which has been proven suitable for use with asphalt cement in constructing pavement wearing surfaces.

Dimensions

8. Asphalt plank shall have the dimensions specified or shown on the plans. Tolerances of plus or minus $\frac{1}{16}$ in. in thickness, plus or minus $\frac{1}{8}$ in. in width, and plus or minus $\frac{1}{4}$ in. in length will be permitted.

NOTE.—The following thicknesses are recognized as standard: $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., and 2 in.

Absorption

9. The absorption of asphalt plank shall not exceed 1.0 per cent by weight.

Brittleness

10. At least 80 per cent of the specimens of each thickness of plank tested shall not show any detrimental cracking when tested in accordance with the method described in Section 16.

Indentation

11. The indentation of asphalt plank, irrespective of thickness, when subjected to the loads prescribed in Section 17, shall be within the following limits:

(*a*) *At 77 F. (25 C.), at the end of 1 min.*—Not less than 12 mils nor more than 27 mils.

(*b*) *At 77 F. (25 C.), at the end of 10 min.*—Not more than that specified in the following table, corresponding to the indentation at 1 min.:

INDENTATION RECORDED AT 1 MIN., NEAREST MIL	MAXIMUM INDENTATION AT 10 MIN., NEAREST HALF MIL
12	21.5
13	23.0
14	24.0
15	25.5
16	27.0
17	28.5
18	30.0
19	31.0
20	32.5
21	33.5
22	35.0
23	36.5
24	37.5
25	39.0
26	40.0
27	41.5

(*c*) *At 125 F. (51.7 C.), at the end of 30 sec.*—Not less than 35 mils nor more than 70 mils.

(*d*) *At 125 F. (51.7 C.), at the end of 300 sec.*—Not more than that specified in the following table (or interpolated therefrom) corresponding to the indentation at 30 sec.:

INDENTATION RECORDED AT 30 SEC., NEAREST MIL	MAXIMUM INDENTATION AT 300 SEC., NEAREST HALF MIL
35	70.0
40	77.0
45	85.0
50	93.0
55	100.0
60	108.0
65	116.0
70	125.0

SAMPLING AND METHODS OF TESTING

Sampling

12. For purpose of tests three planks shall be taken at random by the purchaser for each 1000 planks, or fraction thereof, of each thickness included in the shipment.

Inspection

13. Plank from each lot shall be examined for appearance, straightness of edges, and squareness of corners and measured for width and length. They shall also be calipered at four scattered points each, with a micrometer having flat bearing surfaces at both contact points of not less than ¼ in. in diameter. The average of the readings shall be considered the thickness of the plank.

Weight of Mineral Surfacing

14. The weight of mineral aggregate shall be determined by removing the mineral surfacing aggregate from not less than 1 sq. ft. of mineral surfaced asphalt plank. The aggregate shall be cleaned with any suitable solvent, dried, and sieved on a No. 8 sieve.[1] The amount of aggregate on the sieve shall be weighed and the weight of aggregate per square foot determined.

Absorption Test

15. A specimen 2 by 6 in. shall be cut from the asphalt plank in such a manner that all edges are freshly cut. The specimen shall be accurately weighed to the nearest 0.10 g., immersed in water for 24 hr., removed, and the surface water wiped off with a slightly dampened cloth. The specimen shall than be weighed to the nearest 0.10 g. and the percentage of absorption determined. The time elapsing between the removal of the specimen from the bath and its weighing shall not exceed 1 min.

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[1] For requirements for this sieve see the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, p. 1289.

Brittleness Test

16. Two 6 by 6-in. specimens shall be cut from each of the three sample planks selected in accordance with Section 12. Five of these specimens shall be tested as follows: The specimens shall be immersed in a water bath and maintained at a temperature of 39 to 43 F. (4 to 6 C.) for not less than 3 hr., and then tested immediately upon their removal from the water bath. A smooth, common nail of the size specified in Table I shall be driven into the face at each of two diagonally opposite corners of the specimen not less than $1\frac{1}{2}$ in. nor more than 2 in. from each edge, but not directly over a piece of mineral surfacing aggregate. The specimen shall be supported over its entire base with a timber block 7 by 7 by $1\frac{1}{2}$ in. and the nails shall be driven vertically with repeated blows from a 10-lb. weight falling freely from a constant height of 20 in. above the level of the initial top of the nail or striking assembly. The height shall not be adjusted to compensate for the increased fall caused by the penetration of the nail. The nails shall be supported by a collar or other similar assembly that will hold the nail in a vertical position without friction. Should a nail strike a piece of aggregate covered by the planking matrix, as shown by bending of the nail or by its deflection from the vertical, the specimen shall be discarded and the test repeated on a new specimen. The nails shall penetrate through the asphalt plank, without detrimental cracking, to a depth of not less than 1 in. into the timber block. Cracking shall be considered detrimental when the cracks extend to a point nearer than $\frac{1}{2}$ in. to an edge.

TABLE I. NAIL SIZES REQUIRED FOR BRITTLENESS TEST.

ASPHALT PLANK THICKNESS, IN.	NAIL SIZE	A. S. & W. GAGE NO.	DIAMETER, IN.
$\frac{3}{4}$	12 d.	9	0.148
1	16 d.	8	0.162
$1\frac{1}{4}$	20 d.	6	0.192
$1\frac{1}{2}$	30 d.	5	0.207
2	30 d.	5	0.207

Indentation Test

17. Two 6 by 6-in. specimens from each set of sample planks selected in accordance with Section 12 shall be subjected to the following indentation tests: The specimens shall be brought to a temperature of 77 ± 1 F. (25 ± 0.5 C.) by immersing them in a water bath at this temperature for not less than 2 hr. nor more than 4 hr. Specimens shall also be immersed in water at this temperature during the test. A rod or needle with a hemispherical end 1 in. in diameter shall be applied to the surface (In case of mineral-surfaced plank, the test surface of the specimen shall be the face that does not contain mineral surfacing aggregrate.) of the specimen with a load of

2 lb., the specimen being supported on a polished steel plate.[1] The indentation indicating micrometer dial shall be adjusted to zero and an additional load of 28 lb. applied to the rod or needle. The transfer of the 28-lb. load to the rod shall be completed within 10 sec. following the zero adjustment of the micrometer dial. The readings of the dial at the end of 1 min. and 10 min. from the time of application of the total load shall be taken as the measure of indentation. The 1-min. and 10-min. indentation readings shall be taken at three scattered points on each specimen. The average of the three sets of readings shall be recorded as the 1-min. and 10-min. indentations. The test shall be repeated at 125 ± 1 F. (51.7 ± 0.5 C.), the readings at three points being taken at the end of 30 sec. and 300 sec. If the average indentation of either specimen (or more than one single reading of the three made at each time period) measured as specified above fails to meet the specified requirements in any test, the plank represented by the sample shall be considered to have failed.

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[1] The indentation test may be made with relatively simple apparatus which can be constructed with little expense in almost any laboratory. Where convenience and portability of the indentation apparatus are particularly desirable, the portable indenter devised by J. W. McBurney for indentation testing of asphalt tile (J. W. McBurney, "Indentation of Asphalt Tile," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 591 (1934)) complies with all the above stated requirements for apparatus to make the test. Adaptation of the McBurney indentation test method to asphalt plank has been described in a paper by H. W. Greider and Henri Marc, "Indentation and Compression Shear Tests for Determining Service Stability of Asphalt Plank," *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part II, p. 530 (1937).

Tentative Specifications for
TAR[1]

A.S.T.M. Designation: D 490 - 38 T

ISSUED, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover 14 grades of tar, as follows:

Grades T-1, T-2, T-3, and T-4 for use in prime coat application and light surface treatment,

Grades T-5 and T-6 for use in surface treatment and road mix,

Grades T-7, T-8, and T-9 for use in surface treatment, road mix, plant mix, and seal coat,

Grades T-10, T-11, and T-12 for use in surface treatment, plant mix, penetration, crack filler, and seal coat, and

Grades T.C.B.-5 and T.C.B.-6 for use in patching, surface treatment; also for plant mix and road mix where low-temperature application and quick setting are desired.

Properties

2. The tar shall conform to the requirements prescribed in Table I.

Methods of Sampling and Testing

3. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials, with the exception of the test specified in Paragraph (*d*):

(*a*) *Sampling.*—Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140).[2]

(*b*) *Water.*—Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (A.S.T.M. Designation: D 95).[3]

(*c*) *Specific Gravity.*—Standard Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements, and Soft Tar Pitches (A.S.T.M. Designation: D 70).[4]

(*d*) *Specific Viscosity.*—Standard Method of Test for Specific Viscosity (Method T-54)[5] of the American Association of State Highway Officials. The results shall be reported as specific viscosity compared with water at 25 C. (77 F.).

(*e*) *Float Test.*—Standard Method of Float Test for Bituminous Materials (A.S.T.M. Designation: D 139).[6]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1088.

[3] *Ibid.*, p. 997.

[4] *Ibid.*, p. 1110.

[5] See "Standard Specifications for Highway Materials and Methods of Sampling and Testing," The Am. Assn. State Highway Officials, p. 159 (1935).

[6] 1936 Book of A.S.T.M. Standards, Part II, p. 1061.

TABLE I.—REQUIREMENTS FOR TAR.

		Grade T-1	Grade T-2	Grade T-3	Grade T-4	Grade T-5	Grade T-6	Grade T-7	Grade T-8	Grade T-9	Grade T-10	Grade T-11	Grade T-12	Grade T.C.B.-5	Grade T.C.B.-6
Water by volume, max., per cent		2.00	2.00	2.00	2.00	1.5	1.5	1.0 max.	none	none	none	none	none	1.0	1.0
Specific gravity at 25/25 C. (77/77 F.), min.		1.08	1.08	1.09	1.09	1.10	1.10	1.12	1.14	1.14	1.15	1.16	1.16	1.09	1.09
Specific viscosity,[a] Engler, 50 cc.	at 40 C. (104 F.)	5 to 8	8 to 13	13 to 22	22 to 35										
	at 50 C. (122 F.)					17 to 26	26 to 40							17 to 26	26 to 40
Float test[a]	at 32 C. (89.6 F.)							50 to 80	80 to 120	120 to 200					
	at 50 C. (122 F.)										75 to 100	100 to 150	150 to 220		
Distillation test on water-free material	Total distillate by weight: to 170 C.	7.0–	7.0–	7.0–	5.0–	5.0–	5.0–	3.0	1.0	1.0	1.0	1.0	1.0	2.0 to 8.0	2.0 to 8.0
	to 200 C.													5.0+	5.0+
	to 235 C.													8.0 to 18.0	8.0 to 18.0
	to 270 C.	35.0–	35.0–	30.0–	30.0–	25.0–	25.0–	20.0–	15.0–	15.0–	10.0–	10.0–	10.0–		
	to 300 C.	45.0–	45.0–	40.0–	40.0–	35.0–	35.0–	30.0–	25.0–	25.0–	20.0–	20.0–	20.0–	35.0–	35.0–
Softening point (ring-and-ball method) of residue from distillation test		60 C. (140 F.) max.	65 C. (149 F.) max.[b] 35 to 65 C. (95 to 149 F.)[c]	35 to 65 C. (95 to 149 F.)	35 to 65 C. (95 to 149 F.)	35 to 70 C. (95 to 158 F.)	35 to 70 C. (95 to 158 F.)	35 to 70 C. (95 to 158 F.)	35 to 70 C. (95 to 158 F.)	35 to 70 C. (95 to 158 F.)	40 to 70 C. (104 to 158 F.)	40 to 70 C. (104 to 158 F.)	40 to 70 C. (104 to 158 F.)	40 to 70 C. (104 to 158 F.)	40 to 70 C. (104 to 158 F.)
Total bitumen (soluble in carbon disulfide) by weight, min., per cent		88	88	88	88	83	83	78	78	78	75	75	75	80	80

[a] The consistency limits are subdivided into Grades T-1 to T-12, inclusive, and Grades T.C.B.-5, T.C.B.-6, so that material may be chosen to meet the local conditions of temperature, road conditions, and climate.

[b] When used as a primer.

[c] When used for surface treatment.

(*f*) *Distillation.*—Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (A.S.T.M. Designation: D 20).[7]

(*g*) *Softening Point.*—Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (A.S.T.M. Designation: D 36).[8]

(*h*) *Total Bitumen.*—Standard Method of Test for the Determination of Bitumen (A.S.T.M. Designation: D 4).[9]

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[7] 1936 Book of A.S.T.M. Standards, p. 1053.

[8] *Ibid.*, p. 1098.

[9] *Ibid.*, p. 1041.

TENTATIVE SPECIFICATIONS
FOR
CRUSHED SLAG FOR BITUMINOUS CONCRETE BASE AND SURFACE COURSES[1]

A.S.T.M. Designation: D 485 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestion for revisions should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the quality and grading of crushed slag to be used in the construction of the following types of bituminous concrete mixtures for pavements:

Open-mix bituminous concrete base,
Closed-mix bituminous concrete base,
Bituminous concrete binder courses,
Coarse-graded bituminous concrete pavements, and
Fine-graded bituminous concrete pavements (modified Topeka, or stone-filled sheet asphalt).

General Characteristics

2. The crushed slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Physical Properties

3. The crushed slag shall conform to the following requirement (Note 1):

Weight per cubic foot..................................not less than 70 lb.

NOTE 1.—The requirements for physical properties of slag incorporated in these specifications are recommended as the minimum requirements for quality. It is not expected, however, that these limits for quality will be applicable to all localities and conditions.

Sizes

4. Alternate sizes of crushed slag for use as coarse aggregate for the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

These specifications are in effect a revision and consolidation of, and replace the former Standard Specifications for Broken Slag for Bituminous Concrete (Coarse-Graded Aggregate Type) (D 160 – 27), for Broken Slag for Bituminous Concrete (Fine-Graded Aggregate Type) (D 161 – 27), and for Broken Slag for Bituminous Concrete Base (D 196 – 27), which specifications were accordingly discontinued in 1938.

TABLE I.—GROUP A SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight								
		$2\frac{1}{2}$ in.	2 in.	$1\frac{1}{2}$ in.	1 in.	$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{8}$ in.	No. 4	No. 8
2A	1 to 2 in.	100	90 to 100	35 to 70	0 to 15	....	....	....	....	.....
3A	$\frac{1}{2}$ to 1 in.	...	....	100	90 to 100	....	0 to 15	....	....	.....
23A	$\frac{1}{2}$ to 2 in.	100	90 to 100	....	20 to 55	....	0 to 15	....	0 to 5	.....
234A	No. 4 to 2 in.	100	95 to 100	....	35 to 70	....	10 to 30	....	0 to 5	.....
34A	No. 4 to 1 in.	...	....	100	90 to 100	....	25 to 60	....	0 to 10	.....
4A	No. 4 to $\frac{1}{2}$ in.	...	....	....	....	100	90 to 100	40 to 75	0 to 15	0 to 5
3A (Modified)	No. 4 to 1 in.	...	....	100	90 to 100	40 to 75	5 to 20	....	0 to 5	.....
5B (Modified)	No. 8 to $\frac{3}{8}$ in.	...	....	....	....	....	100	90 to 100	10 to 30	0 to 8

TABLE II.—GROUP B SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight									
		3 in.	$2\frac{1}{2}$ in.	2 in	$1\frac{1}{2}$ in.	1 in.	$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{8}$ in.	No. 4	No. 8
2B	$1\frac{1}{2}$ to $2\frac{1}{2}$ in.	100	90 to 100	35 to 70	0 to 15	....	....	......	....	....	.....
3B	$\frac{3}{4}$ to $1\frac{1}{2}$ in.	...	....	100	90 to 100	20 to 55	0 to 15	......	....	....	.....
23B	$\frac{3}{4}$ to $2\frac{1}{2}$ in.	100	90 to 100	....	25 to 60	....	0 to 10	......	....	....	.....
34B	$\frac{3}{8}$ to $1\frac{1}{2}$ in.	...	....	100	90 to 100	....	30 to 65	......	0 to 10	0 to 5	.....
345B	No. 4 to $1\frac{1}{2}$ in.	...	....	100	95 to 100	....	35 to 70	......	10 to 30	0 to 5	.....
3A (Modified)	No. 4 to 1 in.	...	....	....	100	90 to 100	40 to 75	5 to 20	....	0 to 5	.....
45B	No. 4 to $\frac{3}{4}$ in.	...	....	....	....	100	90 to 100	......	20 to 55	0 to 10	0 to 5
5B	No. 4 to $\frac{3}{8}$ in.	...	....	....	....	....	....	100	90 to 100	0 to 20	0 to 5
5B (Modified)	No. 8 to $\frac{3}{8}$ in.	...	....	....	....	....	....	100	90 to 100	10 to 30	0 to 8

several bituminous concrete mixtures, and for slag chips, shall be as designated in the following table (Notes 2 and 3):

	GROUP A SIZES	GROUP B SIZES
Open mix, bituminous concrete base	2A	2B
	23A	23B
	3A	3B
Closed mix, bituminous concrete base	234A	34B
	34A	345B
Coarse-graded, bituminous concrete surface	3A (Modified)	3A (Modified)
	34A	45B
Fine-graded, bituminous concrete surface	4A	5B
Slag chips for seal coat	4A	5B
	5B (Modified)	5B (Modified)
Binder course	34A	45B

NOTE 2.—An appropriate size should be selected for each use, depending upon local construction and service conditions. It is not intended that sizes from both groups will be selected for any one locality. In any marketing area it is expected that specifications will be based on either Group A or Group B, whichever best fits local conditions. Sizes have been selected from the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1]

NOTE 3.—For mixtures prepared at plants suitably equipped for control of aggregate gradings and proportions, other appropriate sizes may be selected from Tables I or II of the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1] The selected sizes should be such that, when combined in the finished mixture, they will conform to grading requirements for the finished mixture.

Sieve Analysis

5. The several sizes of crushed slag, when tested by means of laboratory sieves having square openings, shall conform to the requirements shown in Table I or Table II.

Methods of Sampling and Testing

6. The crushed slag shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[2]

(*b*) *Weight per Cubic Foot.*—Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29).[3, 4]

(*c*) *Sieve Analysis.*—Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregate (A.S.T.M. Designation: C 136 – 38 T).[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 918 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 910.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1092.

[3] *Ibid.*, p. 364.

[4] A tentative revision of this method appears on p. 817.

[5] See p. 808.

TENTATIVE SPECIFICATIONS
FOR
CRUSHED STONE FOR BITUMINOUS CONCRETE BASE AND SURFACE COURSES[1]

A.S.T.M. Designation: D 486 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the quality and grading of crushed stone to be used in the construction of the following types of bituminous concrete mixtures for pavements:

Open-mix bituminous concrete base,
Closed-mix bituminous concrete base,
Bituminous concrete binder courses,
Coarse-graded bituminous concrete pavements, and
Fine-graded bituminous concrete pavements (modified Topeka, or stone-filled sheet asphalt).

General Characteristics

2. The crushed stone shall consist of clean, tough, durable fragments free from an excess of flat, elongated, soft, or disintegrated pieces, and free from stone coated with dirt or other objectionable matter.

Physical Properties

3. The crushed stone shall conform to the following requirements (Note 1):

	STONE FOR USE IN BASE COURSES	STONE FOR USE IN SURFACE AND BINDER COURSES
Wear	not more than 7 per cent	not more than 6 per cent
Toughness	not less than 6	not less than 6

NOTE 1.—The requirements for physical properties of stone incorporated in these specifications are recommended as the minimum requirements for quality. It is not expected, however, that these limits for quality will be applicable to all localities and conditions.

Sizes

4. Alternate sizes of crushed stone for use as coarse aggregate for the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

These specifications are in effect a revision and consolidation of, and replace the former Standard Specifications for Broken Stone for Bituminous Concrete Surface (D 194 - 29), and Tentative Specifications for Broken Stone for Bituminous Concrete Base (D 193 - 29 T), which specifications were accordingly discontinued in 1938.

TABLE I.—GROUP A SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight								
		2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 8
2A	1 to 2 in.	100	90 to 100	35 to 70	0 to 15	....	....	....	....	.....
3A	½ to 1 in.	...	....	100	90 to 100	....	0 to 15	....	....	.....
23A	½ to 2 in.	100	90 to 100	....	20 to 55	....	0 to 15	....	0 to 5	.....
234A	No. 4 to 2 in.	100	95 to 100	....	35 to 70	....	10 to 30	....	0 to 5	.....
34A	No. 4 to 1 in.	...	....	100	90 to 100	....	25 to 60	....	0 to 10	.....
4A	No. 4 to ½ in.	...	....	....	....	100	90 to 100	40 to 75	0 to 15	0 to 5
3A (Modified)	No. 4 to 1 in.	...	....	100	90 to 100	40 to 75	5 to 20	....	0 to 5	.....
5B (Modified)	No. 8 to ⅜ in.	...	....	....	....	....	100	90 to 100	10 to 30	0 to 8

TABLE II.—GROUP B SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight									
		3 in.	2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 8
2B	1½ to 2½ in.	100	90 to 100	35 to 70	0 to 15	....	....	......	....	....	.....
3B	¾ to 1½ in.	...	....	100	90 to 100	20 to 55	0 to 15	......	....	....	.....
23B	¾ to 1½ in.	100	90 to 100	....	25 to 60	....	0 to 10	......	....	....	.....
34B	⅜ to 1½ in.	...	....	100	90 to 100	....	30 to 65	......	0 to 10	0 to 5	.....
345B	No. 4 to 1½ in.	...	....	100	95 to 100	....	35 to 70	......	10 to 30	0 to 5	.....
3A (Modified)	No. 4 to 1 in.	...	....	....	100	90 to 100	40 to 75	5 to 20	....	0 to 5	.....
45B	No. 4 to ¾ in.	...	....	....	....	100	90 to 100	......	20 to 55	0 to 10	0 to 5
5B	No. 4 to ⅜ in.	...	....	....	....	....	....	100	90 to 100	0 to 20	0 to 5
5B (Modified)	No. 8 to ⅜ in.	...	....	....	....	....	....	100	90 to 100	10 to 30	0 to 8

several bituminous concrete mixtures, and for stone chips, shall be as designated in the following table (Notes 2 and 3):

	GROUP A SIZES	GROUP B SIZES
Open mix, bituminous concrete base	2A	2B
	23A	23B
	3A	3B
Closed mix, bituminous concrete base	234A	34B
	34A	345B
Coarse-graded, bituminous concrete surface	3A (Modified)	3A (Modified)
	34A	45B
Fine-graded, bituminous concrete surface	4A	5B
Stone chips for seal coat	4A	5B
	5B (Modified)	5B (Modified)
Binder course	34A	45B

NOTE 2.—An appropriate size should be selected for each use, depending upon local construction and service conditions. It is not intended that sizes from both groups will be selected for any one locality. In any marketing area it is expected that specifications will be based on either Group A or Group B, whichever best fits local conditions. Sizes have been selected from the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1]

NOTE 3.—For mixtures prepared at plants suitably equipped for control of aggregate gradings and proportions, other appropriate sizes may be selected from Tables I or II of the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1] The selected sizes should be such that, when combined in the finished mixture, they will conform to grading requirements for the finished mixture.

Sieve Analysis

5. The several sizes of crushed stone, when tested by means of laboratory sieves having square openings, shall conform to the requirements shown in Table I or Table II.

Methods of Sampling and Testing

6. The crushed stone shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[2]

(*b*) *Wear.*—Standard Method of Test for Abrasion of Rock by Use of the Deval Machine (A.S.T.M. Designation: D 2).[3]

(*c*) *Toughness.*—Standard Method of Test for Toughness of Rock (A.S.T.M. Designation: D 3).[4]

(*d*) *Sieve Analysis.*—Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates (A.S.T.M. Designation: C 136 – 38 T).[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol 37, Part I, p. 918 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 910.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1092.

[3] *Ibid.*, p 1040.

[4] *Ibid.*, p. 1114.

[5] See p. 808.

TENTATIVE SPECIFICATIONS
FOR
CRUSHED SLAG FOR BITUMINOUS MACADAM BASE AND SURFACE COURSES[1]

A.S.T.M. Designation: D 487 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the quality and grading of crushed slag to be used in the construction of bituminous macadam base and surface courses.

General Characteristics

2. The crushed slag shall be air-cooled blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Physical Properties

3. The crushed slag shall conform to the following requirements (Note 1):

	WEIGHT PER CUBIC FOOT, LB.
Slag for use in base courses	not less than 65
Slag for use in surface courses	not less than 70

NOTE 1.—The requirements for physical properties of slag incorporated in these specifications are recommended as the minimum requirements for quality. It is not expected, however, that these limits for quality will be applicable to all localities and conditions.

Sizes

4. The sizes of crushed slag for the various uses shall be as designated in the following table (Notes 2 and 3):

	GROUP A SIZES	GROUP B SIZES
Coarse slag	1A 12A 2A	1B 12B 2B
Choke slag	3A 4A 4A (Modified)	3B 4B 45B
Slag chips for seal coat	5B (Modified)	5B (Modified)

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

These specifications are in effect a revision and consolidation of, and replace the former Standard Specifications for Broken Slag for Bituminous Macadam Wearing Course (D 159 – 27), and for Broken Slag for Bituminous Macadam Base (D 195 – 27), which specifications were accordingly discontinued in 1938.

TABLE I.—GROUP A SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight										
		4 in.	3½ in.	2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 8
1A	2 to 3½ in.	100	90 to 100	...	0 to 15	...	...	...	...	...	...	...
12A	1 to 3½ in.	100	90 to 100	...	25 to 60	...	0 to 15	...	...	...	...	...
2A	1 to 2 in.	...	...	100	90 to 100	35 to 70	0 to 15	...	...	...	...	...
3A	½ to 1 in.	...	...	...	...	100	90 to 100	...	0 to 15	...	...	...
4A	No. 4 to ½ in.	...	...	...	...	...	...	100	90 to 100	40 to 75	0 to 15	0 to 5
4A (Modified)	No. 8 to ½ in.	...	...	...	...	...	...	100	90 to 100	40 to 70	5 to 25	0 to 5
5B (Modified)	No. 8 to ⅜ in.	...	...	...	...	...	...	...	100	90 to 100	10 to 30	0 to 8

TABLE II.—GROUP B SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight											
		4 in.	3½ in.	3 in.	2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 8
1B	2½ to 3½ in.	100	90 to 100	35 to 70	0 to 15	...	...	...	...	...	...	...	...
12B	1½ to 3½ in.	100	90 to 100	...	35 to 70	...	0 to 15	...	...	...	...	...	...
2B	1½ to 2½ in.	...	...	100	90 to 100	35 to 70	0 to 15	...	...	...	...	...	...
3B	¾ to 1½ in.	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	...	...	...
4B	⅜ to ¾ in.	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	...
45B	No. 4 to ¾ in.	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5
5B (Modified)	No. 8 to ⅜ in.	...	...	...	...	...	...	...	...	100	90 to 100	10 to 30	0 to 8

NOTE 2.—An appropriate size should be selected for each use, depending upon local construction and service conditions. It is not intended that sizes from both groups will be selected for any one locality. In any marketing area it is expected that specifications will be based on either Group A or Group B, whichever best fits local conditions. Sizes have been selected from the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1]

NOTE 3.—The sizes of choke slag should be adapted to the size of coarse slag. The following combinations of sizes are recommended:

COARSE SLAG SIZES	CHOKE SLAG SIZES
1A	3A
12A	4A or 4A (Modified)
2A	4A or 4A (Modified)
1B	3B
12B	4B or 45B
2B	4B or 45B

Sieve Analysis

5. The several sizes of crushed slag, when tested by means of laboratory sieves having square openings, shall conform to the requirements shown in Table I or Table II.

Methods of Sampling and Testing

6. The crushed slag shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[2]

(*b*) *Weight per Cubic Foot.*—Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29).[3, 4]

(*c*) *Sieve Analysis.*—Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates (A.S.T.M. Designation: C 136 – 38 T).[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 918 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 910.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1092.

[3] *Ibid.*, p. 364.

[4] A tentative revision of this method appears on p. 817.

[5] See p. 808.

TENTATIVE SPECIFICATIONS
FOR
CRUSHED STONE FOR BITUMINOUS MACADAM BASE AND SURFACE COURSES[1]

A.S.T.M. Designation: D 192 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1929; REVISED AND REISSUED AS TENTATIVE, 1938.

Scope

1. These specifications cover the quality and grading of crushed stone to be used in the construction of bituminous macadam base and surface courses.

General Characteristics

2. The crushed stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, and free from stone coated with dirt or other objectionable matter.

Physical Properties

3. The crushed stone shall conform to the following requirements (Note 1):

	STONE FOR USE IN BASE COURSES	STONE FOR USE IN SURFACE COURSES
Wear	not more than 7 per cent	not more than 6 per cent
Toughness	not less than 6	not less than 6

NOTE 1.—The requirements for physical properties of stone incorporated in these specifications are recommended as the minimum requirements for quality. It is not expected, however, that these limits for quality will be applicable to all localities and conditions.

Sizes

4. The sizes of crushed stone for the various uses shall be as designated in the following table (Notes 2 and 3):

	GROUP A SIZES	GROUP B SIZES
Coarse stone	1A	1B
	12A	12B
	2A	2B
Choke stone	3A	3B
	4A	4B
	4A (Modified)	45B
Stone chips for seal coat	5B (Modified)	5B (Modified)

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

These specifications are in effect a revision of, and replace the former Standard Specifications for Broken Stone for Bituminous Macadam (D 192 – 29), which specifications were accordingly discontinued in 1938.

TABLE I.—GROUP A SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight										
		4 in.	3½ in.	2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 8
1A	2 to 3½ in.	100	90 to 100	...	0 to 15	...	...	...	...	...	...	...
12A	1 to 3½ in.	100	90 to 100	...	25 to 60	...	0 to 15	...	...	...	...	...
2A	1 to 2 in.	...	...	100	90 to 100	35 to 70	0 to 15	...	...	...	...	...
3A	½ to 1 in.	...	...	...	...	100	90 to 100	...	0 to 15	...	...	...
4A	No. 4 to ½ in.	...	...	...	...	...	...	100	90 to 100	40 to 75	0 to 15	0 to 5
4A (Modified)	No. 8 to ½ in.	...	...	...	...	...	...	100	90 to 100	40 to 70	5 to 25	0 to 5
5B (Modified)	No. 8 to ⅜ in.	...	...	...	...	...	...	...	100	90 to 100	10 to 30	0 to 8

TABLE II.—GROUP B SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight											
		4 in.	3½ in.	3 in.	2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4	No. 8
1B	2½ to 3½ in.	100	90 to 100	35 to 70	0 to 15	...	...	...	...	...	...	...	...
12B	1½ to 3½ in.	100	90 to 100	...	35 to 70	...	0 to 15	...	...	...	...	...	...
2B	1½ to 2½ in.	...	...	100	90 to 100	35 to 70	0 to 15	...	...	...	...	...	...
3B	¾ to 1½ in.	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	...	...	...
4B	⅜ to ¾ in.	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	...
45B	No. 4 to ¾ in.	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5
5B (Modified)	No. 8 to ⅜ in.	...	...	...	...	...	...	...	...	100	90 to 100	10 to 30	0 to 8

NOTE 2.—An appropriate size should be selected for each use, depending upon local construction and service conditions. It is not intended that sizes from both groups will be selected for any one locality. In any marketing area it is expected that specifications will be based on either Group A or Group B, whichever best fits local conditions. Sizes have been selected from the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1]

NOTE 3.—The sizes of choke stone should be adapted to the size of coarse stone. The following combinations of sizes are recommended:

COARSE STONE SIZES	CHOKE STONE SIZES
1A	3A
12A	4A or 4A (Modified)
2A	4A or 4A (Modified)
1B	3B
12B	4B or 45B
2B	4B or 45B

Sieve Analysis

5. The several sizes of crushed stone, when tested by means of laboratory sieves having square openings, shall conform to the requirements shown in Table I or Table II.

Methods of Sampling and Testing

6. The crushed stone shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[2]

(*b*) *Wear.*—Standard Method of Test for Abrasion of Rock by Use of the Deval Machine (A.S.T.M. Designation: D 2).[3]

(*c*) *Toughness.*—Standard Method of Test for Toughness of Rock (A.S.T.M. Designation: D 3).[4]

(*d*) *Sieve Analysis.*—Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates (A.S.T.M. Designation: C 136 – 38 T).[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 918 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 910.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1092.

[3] *Ibid.*, p. 1040.

[4] *Ibid.*, p. 1114.

[5] See p. 808.

TENTATIVE SPECIFICATIONS
FOR
CRUSHED SLAG FOR WATERBOUND BASE AND SURFACE COURSES[1]

A.S.T.M. Designation: D 488 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1920; ADOPTED, 1923; REVISED AND REISSUED AS TENTATIVE, 1938

Scope

1. These specifications cover the quality and grading of crushed slag and slag screenings to be used in the construction of waterbound base and surface courses.

General Characteristics

2. The crushed slag shall be air-cooled, blast-furnace slag and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter.

Physical Properties

3. The crushed slag shall conform to the following requirements (Note 1):

	WEIGHT PER CUBIC FOOT, LB.
Slag for use in base courses	65
Slag for use in surface courses	70

NOTE 1.—The requirements for physical properties of slag incorporated in these specifications are recommended as the minimum requirements for quality. It is not expected, however, that these limits for quality will be applicable to all localities and conditions.

Sizes

4. The sizes of crushed slag for the various uses shall be as designated in the following table (Note 2):

	GROUP A SIZES	GROUP B SIZES
Coarse slag	1A 12A 2A	1B 12B 2B
Screenings	5A	6B

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

These specifications are in effect a revision and consolidation of, and replace the former Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (D 65 - 23), and for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 - 23), which specifications were accordingly discontinued in 1938.

TABLE I.—GROUP A SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight								
		4 in.	$3\frac{1}{2}$ in.	$2\frac{1}{2}$ in.	2 in.	$1\frac{1}{2}$ in.	1 in.	$\frac{1}{2}$ in.	No. 4	No. 100
1A	2 to $3\frac{1}{2}$ in.	100	90 to 100	...	0 to 15	....	......	...	....	....
12A	1 to $3\frac{1}{2}$ in.	100	90 to 100	...	25 to 60	....	0 to 15	...	....	....
2A	1 to 2 in.	...	....	100	90 to 100	35 to 70	0 to 15	...	....	....
5A	0 to No. 4	...	....	...	....	....	......	100	75 to 100	10 to 30

TABLE II.—GROUP B SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight								
		4 in.	$3\frac{1}{2}$ in.	3 in.	$2\frac{1}{2}$ in.	2 in.	$1\frac{1}{2}$ in.	$\frac{3}{8}$ in.	No. 4	No. 100
1B	$2\frac{1}{2}$ to $3\frac{1}{2}$ in.	100	90 to 100	35 to 70	0 to 15	....	......	...	....	....
12B	$1\frac{1}{2}$ to $3\frac{1}{2}$ in.	100	90 to 100	....	35 to 70	....	0 to 15	...	....	....
2B	$1\frac{1}{2}$ to $2\frac{1}{2}$ in.	...	....	100	90 to 100	35 to 70	0 to 15	...	....	....
6B	0 to No. 4	...	....	....	....	....	......	100	85 to 100	10 to 30

NOTE 2.—An appropriate size should be selected for each use, depending upon local construction and service conditions. It is not intended that sizes from both groups will be selected for any one locality. In any marketing area it is expected that specifications will be based on either Group A or Group B, whichever best fits local conditions. Sizes have been selected from the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1]

Sieve Analysis

5. The several sizes of crushed slag, when tested by means of laboratory sieves having square openings, shall conform to the requirements shown in Table I or Table II.

Methods of Sampling and Testing

6. The crushed slag shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[2]

(*b*) *Weight per Cubic Foot.*—Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29).[3, 4]

(*c*) *Sieve Analysis.*—Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregate (A.S.T.M. Designation: C 136 – 38 T).[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol 37, Part I, p. 918 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 910.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1092.

[3] *Ibid.*, p. 364.

[4] A tentative revision of this method appears on p. 817.

[5] See p. 808.

TENTATIVE SPECIFICATIONS
FOR
CRUSHED STONE FOR WATERBOUND BASE AND SURFACE COURSES[1]

A.S.T.M. Designation: D 489 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover the quality and grading of crushed stone and stone screenings to be used in the construction of waterbound base and surface courses.

General Characteristics

2. (*a*) The crushed stone shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces.

(*b*) The stone for screenings shall be of suitable binding quality.

Physical Properties

3. The crushed stone shall conform to the following requirements (Note 1):

	STONE FOR USE IN BASE COURSES	STONE FOR USE IN SURFACE COURSES
Wear	not more than 8 per cent	not more than 6 per cent
Toughness	....	not less than 6

NOTE 1.—The requirements for physical properties of stone incorporated in these specifications are recommended as the minimum requirements for quality. It is not expected, however, that these limits for quality will be applicable to all localities and conditions.

Sizes

4. The sizes of crushed stone for the various uses shall be as designated in the following table (Note 2):

	GROUP A SIZES	GROUP B SIZES
Coarse stone	1A 12A 2A	1B 12B 2B
Screenings	5A	6B

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

These specifications are in effect a revision and consolidation of, and replace the former Tentative Specifications for Broken Stone for Waterbound Base (D 190 - 29 T), and Standard Specifications for Waterbound Macadam Surface Course (D 191 - 29), which specifications were accordingly discontinued in 1938.

TABLE I.—GROUP A SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight								
		4 in.	$3\frac{1}{2}$ in.	$2\frac{1}{2}$ in.	2 in.	$1\frac{1}{2}$ in.	1 in.	$\frac{1}{2}$ in.	No. 4	No. 100
1A	2 to $3\frac{1}{2}$ in.	100	90 to 100	...	0 to 15	....	......	...	....	....
12A	1 to $3\frac{1}{2}$ in.	100	90 to 100	...	25 to 60	....	0 to 15	...	....	....
2A	1 to 2 in.	...	....	100	90 to 100	35 to 70	0 to 15	...	....	....
5A	0 to No. 4	...	....	...	....	....	......	100	75 to 100	10 to 30

TABLE II.—GROUP B SIZES, REQUIREMENTS FOR SIEVE ANALYSIS.

Size Number	Nominal Size, Square Openings	Amounts Finer than Each Sieve (Square Openings), per cent by weight								
		4 in.	$3\frac{1}{2}$ in.	3 in.	$2\frac{1}{2}$ in.	2 in.	$1\frac{1}{2}$ in.	$\frac{3}{8}$ in.	No. 4	No. 100
1B	$2\frac{1}{2}$ to $3\frac{1}{2}$ in.	100	90 to 100	35 to 70	0 to 15	....	......	...	....	....
12B	$1\frac{1}{2}$ to $3\frac{1}{2}$ in.	100	90 to 100	....	35 to 70	....	0 to 15	...	....	....
2B	$1\frac{1}{2}$ to $2\frac{1}{2}$ in.	...	....	100	90 to 100	35 to 70	0 to 15	...	....	....
6B	0 to No. 4	...	....	....	....	....	......	100	85 to 100	10 to 30

NOTE 2.—An appropriate size should be selected for each use, depending upon local construction and service conditions. It is not intended that sizes from both groups will be selected for any one locality. In any marketing area it is expected that specifications will be based on either Group A or Group B, whichever best fits local conditions. Sizes have been selected from the Tentative Specifications for Standard Sizes of Coarse Aggregate for Highway Construction (A.S.T.M. Designation: D 448 – 37 T) of the American Society for Testing Materials.[1]

Sieve Analysis

5. The several sizes of crushed stone, when tested by means of laboratory sieves having square openings, shall conform to the requirements shown in Table I or Table II.

Methods of Sampling and Testing

6. The crushed stone shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand, and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[2]

(*b*) *Wear.*—Standard Method of Test for Abrasion of Rock by Use of the Deval Machine (A.S.T.M. Designation: D 2).[3]

(*c*) *Toughness.*—Standard Method of Test for Toughness of Rock (A.S.T.M. Designation: D 3).[4]

(*d*) *Sieve Analysis.*—Tentative Method of Test for Sieve Analysis of Fine and Coarse Aggregates (A.S.T.M. Designation: C 136 - 38 T).[5]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol 37, Part I, p. 918 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 910.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1092.

[3] *Ibid.*, p. 1040.

[4] *Ibid.*, p. 1114.

[5] See p. 808.

TENTATIVE METHOD OF PREPARING SOIL SAMPLES AS RECEIVED FROM THE FIELD FOR MECHANICAL ANALYSIS AND THE DETERMINATION OF THE SUBGRADE SOIL CONSTANTS[1]

A.S.T.M. Designation: D 421 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935; Revised, 1938.

Scope

1. This method covers the preparation of soil samples as received from the field for mechanical analysis and the determination of the subgrade soil constants.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance sensitive to 0.1 g.

(*b*) *Mortar.*—A mortar and rubber-covered pestle suitable for breaking up the aggregations of soil particles.

(*c*) *Sieves.*—A series of sieves, of square-mesh wire cloth, conforming to the requirements of the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2] The sizes required are shown in Table I.

(*d*) *Sampler.*—A riffle sampler or sample splitter, for quartering the samples.

Table I.—Requirements for Sieve Openings and Wire Diameters With Permissible Variations.

Mesh Designation, U. S. Standard Sieve Series	Sieve Opening		Wire Diameter		Tolerances, per cent			
					Average Opening	Wire Diameter		Maximum Opening
	mm.	in.	mm.	in.		Under	Over	
No. 4	4.76	0.1870	1.27	0.050	±3	15	30	10
No. 10	2.00	0.0787	0.76	0.0299	±3	15	30	10
No. 40	0.42	0.0165	0.25	0.0098	±5	15	30	25
No. 200	0.074	0.0029	0.053	0.0021	±8	15	35	60

Sampling

3. The soil sample as received from the field shall be dried thoroughly in the air and the aggregations shall then be thoroughly broken up in the

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.

[2] See p. 1289.

mortar with a rubber-covered pestle. A representative test sample of the amount required to perform the desired tests shall then be selected by the method of quartering or by the use of a sampler. The amounts of material required to perform the individual tests are as follows:

(*a*) *Mechanical Analysis.*—For the mechanical analysis, material passing a No. 10 sieve is required in amounts equal to 115 g. of sandy soils and 65 g. of either silt or clay soils.

(*b*) *Physical Tests.*—For the physical tests, material passing the No. 40 sieve is required in total amount equal to 200 g., allocated as follows:

	GRAMS
Liquid limit	30
Plastic limit	15
Centrifuge moisture equivalent	10
Field moisture equivalent	50
Volumetric shrinkage	30
Check tests	65

Preparation of Test Sample

4. (*a*) That portion of the air-dried sample selected for purpose of tests shall be weighed and the weight recorded as the weight of the total test sample uncorrected for hygroscopic moisture. The test sample shall be separated by sieving with a No. 10 sieve. That fraction retained on the No. 10 sieve shall be ground in a mortar with a rubber-covered pestle until the aggregations of soil particles are broken up into the separate grains. The ground soil shall then be separated into two fractions by sieving with a No. 10 sieve.

(*b*) That fraction retained after the second sieving shall be washed free of all fine material, dried, and weighed. This weight shall be recorded as the weight of coarse material. The coarse material after being washed and dried shall be sieved on the No. 4 sieve and the weight retained on the No. 4 sieve recorded.

Test Sample for Mechanical Analysis

5. The fractions passing the No. 10 sieve in both sieving operations shall be thoroughly mixed together, and by the method of quartering or the use of a sampler a portion weighing approximately 115 g. for sandy soils and approximately 65 g. for silt and clay soils shall be selected for mechanical analysis.

Test Sample for Subgrade Soil Constants

6. The remaining portion of the material passing the No. 10 sieve shall then be separated into two parts by means of a No. 40 sieve. The fraction retained on the No. 40 sieve shall be discarded. The fraction passing the No. 40 sieve shall be used for the determination of the subgrade soil constants.

TENTATIVE METHOD OF TEST
FOR
CENTRIFUGE MOISTURE EQUIVALENT OF SOILS[1]

A.S.T.M. Designation: D 425 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

Centrifuge Moisture Equivalent

1. The centrifuge moisture equivalent of a soil is the amount of moisture, expressed as a percentage of the weight of the oven-dried soil, retained by a soil which has been first saturated with water and then subjected to a force equal to one thousand times the force of gravity for one hour.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Gooch Crucible.*—A porcelain Gooch crucible with perforated bottom. The crucible shall be about 1½ in. in height and the diameter shall be about 1 in. at the top and ¾ in. at the bottom, outside dimensions.

(*b*) *Filter Paper.*—A circular piece of filter paper just large enough to cover the inside bottom of the Gooch crucible.

(*c*) *Trunnion Cup.*—A Babcock trunnion cup fitted with a brass cap and with a suitable device for supporting the Gooch crucible ½ in. above the bottom of the cup in such a manner that the water ejected during the centrifuging operation shall not come in contact with the crucible and contents and, furthermore, that air may circulate freely about the crucible within the cup. Suitable fittings for the Babcock cup are shown in Fig. 1.

(*d*) *Centrifuge.*—The centrifuge shall be of such size and so driven that a force equal to one thousand times the force of gravity may be exerted on the center of gravity of the soil sample.

(*e*) *Balance.*—A balance sensitive to 0.1 g.

Sample

3. A 5-g. sample shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.

Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 38 T) of the American Society for Testing Materials.[1]

Number of Tests

4. Tests shall be made in duplicate.

Procedure

5. (*a*) The sample shall be placed in the Gooch crucible, in which has previously been placed a piece of wet filter paper which just covers the bottom of the crucible. The crucible shall be placed in a pan of distilled water and the sample allowed to take up moisture until completely saturated, as indicated by the presence of free water on the surface of the sample. It shall then be placed in a humidifier for at least 12 hr. to insure uniform distribution of moisture throughout the soil mass. All free water then remaining on the surface of the sample shall be poured off, and the crucible placed in a Babcock trunnion cup fitted as described in Section 2 (*c*).

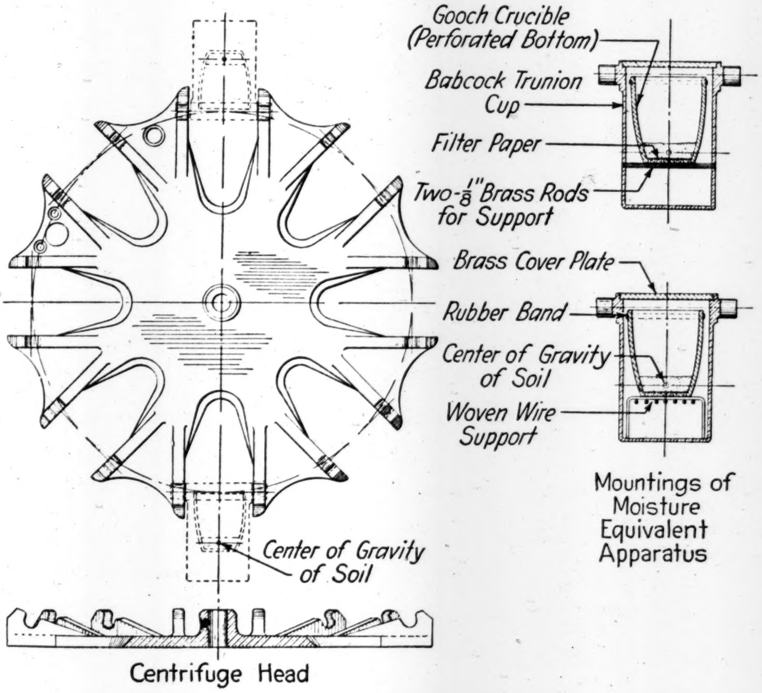
Gooch Crucible (Perforated Bottom)
Babcock Trunion Cup
Filter Paper
Two-$\frac{1}{8}$" Brass Rods for Support
Brass Cover Plate
Rubber Band
Center of Gravity of Soil
Woven Wire Support
Mountings of Moisture Equivalent Apparatus
Center of Gravity of Soil
Centrifuge Head

FIG. 1.—Centrifuge Apparatus.

(*b*) The sample shall be centrifuged for a period of 1 hr. at a speed which, for the diameter of head used, will exert a centrifugal force one thousand times the force of gravity upon the center of gravity of the soil sample. Immediately after centrifuging, the crucible and contents shall be weighed and the weight recorded as the weight of crucible and contents after centrifuging. The sample shall then be oven dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded as the weight of crucible and contents after drying.

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[1] See p. 942.

(*c*) *Water-logging.*—When free water is observed on the top of the sample after the centrifuging operation, the soil is said to have water-logged. This water shall not be removed but shall be weighed with the sample.

Calculation

6. The centrifuge moisture equivalent of the soil shall be calculated by the following formula:

$$\text{Centrifuge moisture equivalent} = \frac{(A - b) - (A_1 - b_1)}{A_1 - (c + b_1)} \times 100$$

where A = the weight of crucible and contents after centrifuging
A_1 = the weight of crucible and contents after drying
c = the weight of crucible
b = the weight of filter paper wet
b_1 = the weight of filter paper dry

Permissible Variation in Duplicate Tests

7. The variation between the two values obtained in the duplicate tests should not exceed 1 per cent for values of the moisture equivalent up to 15 and 2 per cent for values above 15.

TENTATIVE METHOD OF TEST
FOR
FIELD MOISTURE EQUIVALENT OF SOILS[1]

A.S.T.M. Designation: D 426 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

Field Moisture Equivalent

1. The field moisture equivalent of a soil is defined as the minimum moisture content, expressed as a percentage of the weight of the oven-dried soil, at which a drop of water placed on a smoothed surface of the soil will not immediately be absorbed by the soil but will spread out over the surface and give it a shiny appearance.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish.*—A porcelain evaporating dish about 4½ in. in diameter.

(*b*) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about ¾ in. in width.

(*c*) *Pipette.*—A pipette, burette, or similar device for adding water dropwise.

(*d*) *Containers.*—Suitable containers such as matched watch glasses which will prevent loss of moisture during weighing.

(*e*) *Balance.*—A balance sensitive to 0.1 g.

Sample

3. A sample weighing about 50 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve, which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 38 T) of the American Society for Testing Materials.[2]

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.

[2] See p. 942.

Procedure

4. The air-dried sample shall be placed in the evaporating dish and mixed with distilled water. Distilled water shall be added in small amounts and the sample thoroughly mixed after each addition of water. When the wetted soil forms into balls under manipulation, the sample shall be smoothed with a light stroke of the spatula and a drop of water placed on the smoothed surface. If the drop of water disappears in 30 sec. a small increment of water (a few drops) shall be mixed with the sample, and the procedure repeated until the drop of water does not disappear in 30 sec. but spreads over the smoothed surface leaving a shiny appearance. A small portion of the soil on which the last drop of water was placed shall then be removed and placed between two watch glasses or other suitable containers. The weight of the container and wet soil shall be determined and recorded. The sample shall then be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the difference in weight shall be recorded as the weight of water.

Calculation

5. The field moisture equivalent shall be calculated by the following formula:

$$\text{Field moisture equivalent} = \frac{\text{weight of water}}{\text{weight of oven-dried soil}} \times 100$$

TENTATIVE METHOD OF TEST
FOR
LIQUID LIMIT OF SOILS[1]

A.S.T.M. Designation: D 423 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935; Revised, 1938.

Liquid Limit

1. The liquid limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil will just begin to flow when lightly jarred ten times.

Apparatus

2. The apparatus shall consist of the following:

(a) *Evaporating Dish.*—A porcelain evaporating dish about $4\frac{1}{2}$ in. in diameter.

(b) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about $\frac{3}{4}$ in. in width.

(c) *Mechanical Device.*—A mechanical device consisting of a brass dish and carriage, constructed according to the plan and dimensions shown in Fig. 1.

(d) *Grooving Tool.*—A combined grooving tool and gage conforming to the dimensions shown in Fig. 1.

(e) *Containers.*—Suitable containers such as matched watch glasses which will prevent loss of moisture during weighing.

(f) *Balance.*—A balance sensitive to 0.1 g.

HAND METHOD

Sample

3. A sample weighing about 30 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 38 T) of the American Society for Testing Materials.[2]

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.

[2] See p. 942.

Procedure

4. (*a*) The air-dried soil shall be placed in the evaporating dish and thoroughly mixed with distilled water until the mass becomes a thick paste. The mass of soil shall then be shaped into a small layer about $\frac{3}{8}$ in. in thickness at the center and divided into two portions with the grooving tool, as shown in the illustration at the top of Fig. 2.

(*b*) The dish shall be held firmly in one hand, with the groove parallel to the line of sight, and tapped lightly with a horizontal motion against the heel of the other hand ten times. The intensity of the blows shall be such that the effect on the soil sample is equivalent to that produced by 25 shocks applied to a sample of the soil at the same moisture content by dropping the brass cup of the mechanical device through a distance of 1 cm. (0.3937 in.) at the rate of two drops per second.

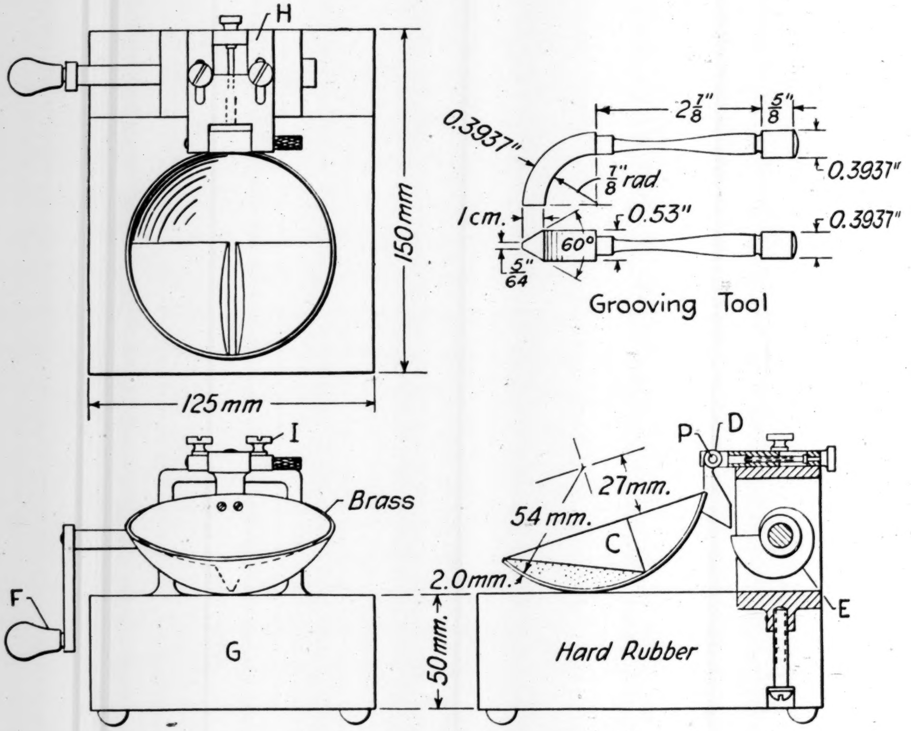
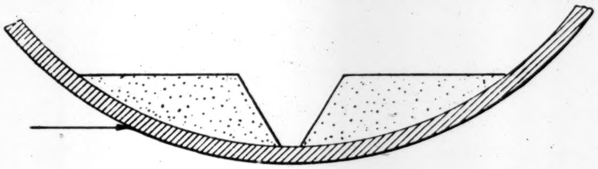


FIG. 1.—Liquid Limit Device.

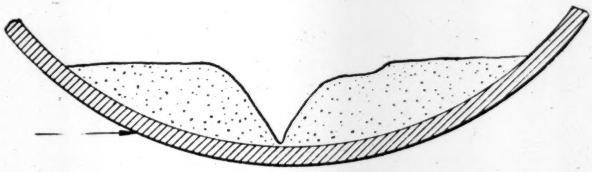
(*c*) If the lower edges of the two soil portions do not flow together, as shown in the illustration at the bottom of Fig. 2, after ten blows have been struck, the moisture content is below the liquid limit. More water shall be added and the procedure repeated. If the lower edges meet before ten blows have been struck, the moisture content is above the liquid limit, and dry soil shall be added and the procedure repeated.

(*d*) When the lower edges of the two portions of the soil cake just flow together as shown in the illustration at the bottom of Fig. 2 after ten blows have been struck, the moisture content equals the liquid limit. To determine definitely whether the two portions are actually joined, the spatula may be used to push one away from the other. If the two portions separate along the original line of division, the end point has not been reached, and the procedure shall be repeated with the addition of a small amount of water.

(*e*) A small quantity of soil from that portion of the soil cake which was flowed shall be removed and placed in a pair of watch glasses or other suitable containers. The container and soil shall then be weighed and the weight recorded. The soil in the container shall be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the loss in weight due to drying shall be recorded as the weight of water.



DIVIDED SOIL CAKE BEFORE TEST



SOIL CAKE AFTER TEST

FIG. 2.—Diagram Illustrating Liquid Limit Test.

Calculation

5. The liquid limit is expressed as the moisture content in percentage of the weight of the oven-dried soil and it shall be calculated by the following formula:

$$\text{Liquid limit} = \frac{\text{weight of water}}{\text{weight of oven-dry soil}} \times 100$$

MECHANICAL METHOD

Calibration of Mechanical Device

6. By means of the gage attached to the grooving tool, and the adjustment plate, *H*, Fig. 1, the height to which the cup, *C*, is lifted shall be adjusted so that the point on the cup which comes in contact with the base is

exactly 1 cm. (0.3937 in.) above the base. The adjustment plate, *H*, shall then be secured by tightening the screws, *I*.

Procedure

7. (*a*) A sample weighing about 100 g. shall be taken from the thoroughly mixed portion of the air-dried soil passing the No. 40 sieve which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 38 T) of the American Society for Testing Materials.[1] This sample shall be placed in the evaporating dish and thoroughly mixed with a measured quantity of distilled water to a putty-like consistency. A portion of this sample shall then be placed in the brass cup in the position shown in Fig. 1, leveled off to a depth of 1 cm., and divided by means of the grooving tool along the diameter through the centerline of the cam follower.

(*b*) The cup shall then be attached to the carriage and by turning the crank, *F*, at the rate of two rotations per second lifted and dropped until the two sides of the sample come into contact at the bottom of the groove along a distance of about ½ in. The number of shocks shall be recorded. The moisture content of the soil shall then be determined on a portion taken from around the groove, by the method previously described in Section 4 in connection with the hand method.

(*c*) The foregoing operations shall be repeated for two additional portions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that the number of shocks required to close the groove will be below and above 25.

Preparation of Flow Curve

8. A "flow curve" representing the relation between moisture contents and corresponding numbers of shocks shall be plotted on a semi-log graph with the moisture contents as abscissae on the arithmetical scale, and the numbers of shocks as ordinates on the logarithmic scale.

Liquid Limit Determination

9. The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil.

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[1] See p. 942.

TENTATIVE METHOD OF MECHANICAL ANALYSIS OF SOILS[1]

A.S.T.M. Designation: D 422 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

Scope

1. This method covers the quantitative determination of the distribution of particle sizes in soils.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance sensitive to 0.1 g.

(*b*) *Stirring Apparatus.*—A special stirring apparatus (Fig. 1) with replaceable stirring paddle (Fig. 2) and specially designed dispersion cup of either of the designs shown in Fig. 3.

(*c*) *Hydrometer.*—A hydrometer graduated in grams of soil per liter of suspension (Fig. 4, *A*) *or* a hydrometer with special shape bulb, graduated in specific gravity, having a range of 0.995 to 1.050 specific gravity and reading 1.000 at 67 F. (19.4 C.) (Fig. 4, *B*).

(*d*) *Glass Graduate.*—A glass graduate 18 in. in height and $2\frac{1}{2}$ in. in diameter and graduated for a volume of 1000 cc.

(*e*) *Thermometer.*—A Fahrenheit thermometer accurate to 1 F. (0.5 C.).

(*f*) *Sieves.*—A series of sieves, conforming to the requirements of the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2] The sieves required are Nos. 20, 40, 60, 140, and 200.

(*g*) *Water Bath.*—A water bath for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory device is an insulated zinc tank which maintains the temperature of the suspension at faucet-water temperature. Such a device is illustrated in Fig. 5.

(*h*) *Beaker.*—A tall form beaker of 400-ml. capacity.

Sample

3. A sample of soil shall be selected by the method of quartering or by the use of a sampler from the material passing the No. 10 sieve. The weight of each sample shall be approximately 115 g. for sandy soils and 65 g. for silt and clay soils and shall be obtained in accordance with the

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.

[2] See p. 1289.

Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 38 T) of the American Society for Testing Materials.[1]

HYGROSCOPIC MOISTURE

Hygroscopic Moisture

4. A 10-g. portion of the sample selected for mechanical analysis shall be used for the determination of the hygroscopic moisture. This portion of the sample shall be weighed, dried to constant weight in an oven at 110 C., weighed, and the results recorded.

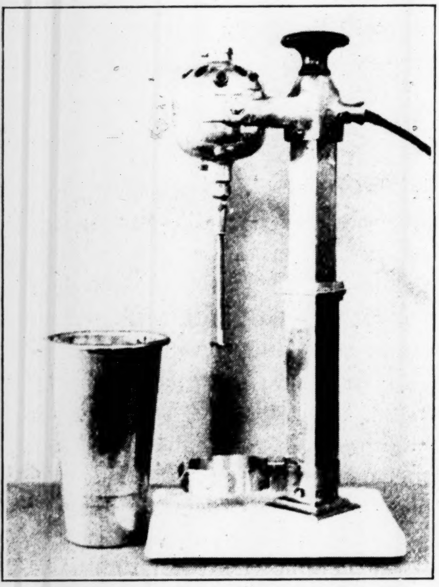

FIG. 1.—Stirring Apparatus.

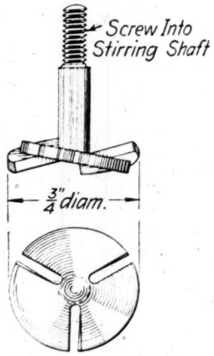

FIG. 2.—Detail of Stirring Paddle.

HYDROMETER TEST

Dispersion of Soil Sample

5. The remainder of the sample selected for mechanical analysis shall be weighed and dispersed by one of the two methods *A* or *B* described below. The method to be used depends on the plasticity index of the soil determined in accordance with the Tentative Method of Test for Plastic Limit and Plasticity Index of Soils (A.S.T.M. Designation: D 424 – 38 T) of the American Society for Testing Materials.[2]

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[1] See p. 942.
[2] See p. 965.

Method A: For Soils Having a Plasticity Index of 20 or Less.—The soil shall be placed in a tall-form beaker, and 200 ml. or more of distilled water added slowly and with constant stirring until the soil is thoroughly wetted. The mixture shall be allowed to stand for a period of at least 18 hr. It shall then be washed into the special dispersion cup and distilled water added until the cup is within 2 in. of being filled. A deflocculating agent, 20 ml. of a solution of sodium silicate crystals ($Na_2SiO_3 \cdot 9\ H_2O$) shall be added. The density of this solution shall be that indicated by one of the following hydrometer readings: hydrometer *A*, 36.5 at 67 F. (19.4 C.); hydrometer *B*, 1.023 at 67 F. (19.4 C.); Baumé hydrometer, 3 deg. at 76 F. (24.4 C.). The contents of the cup shall be mixed by the special stirring apparatus (Note) for a period of 1 min.

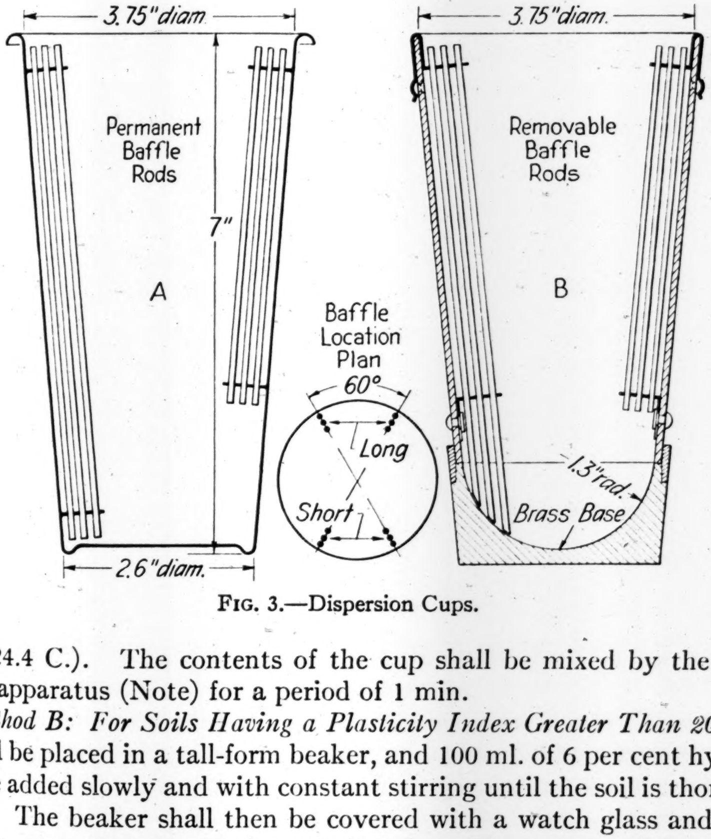

FIG. 3.—Dispersion Cups.

Method B: For Soils Having a Plasticity Index Greater Than 20.—The soil shall be placed in a tall-form beaker, and 100 ml. of 6 per cent hydrogen peroxide added slowly and with constant stirring until the soil is thoroughly wetted. The beaker shall then be covered with a watch glass and placed in an oven at a temperature of 110 C. for 1 hr. The purpose of the peroxide is to assist in the dispersion rather than to remove the organic matter. The beaker shall then be removed from the oven, 100 ml. of distilled water added, and the mixture allowed to stand for at least 18 hr. The mixture shall then be washed into the special dispersion cup, and dispersed (Note) in the same manner and for the same length of time as in method *A*.

NOTE.—It is important in all cases to see that the paddle on the dispersion machine is replaced as soon as it shows signs of wear.

Hydrometer Test

6. (*a*) After dispersion, the mixture shall be transferred to the glass graduate, and distilled water having the same temperature as the constant temperature bath added until the mixture attains a volume of 1000 ml.

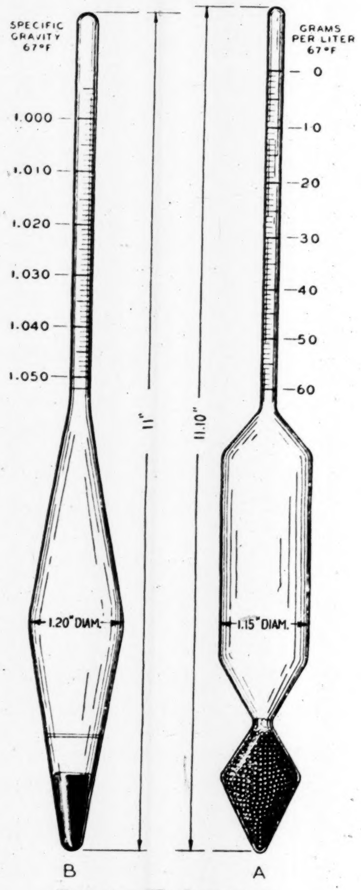
SPECIFIC GRAVITY 67°F
1.000
1.010
1.020
1.030
1.040
1.050
11"
11.10"
1.20" DIAM.
B
GRAMS PER LITER 67°F
0
10
20
30
40
50
60
1.15" DIAM.
A

FIG. 4.—Hydrometers.

The graduate containing the soil suspension shall then be placed in the constant temperature bath. The suspension shall be stirred frequently with a glass rod to prevent settlement of particles in suspension. When the soil suspension attains the temperature of the bath the graduate shall be removed and its contents thoroughly shaken for 1 min., the palm of the hand being used as a stopper over the mouth of the graduate.

(*b*) At the conclusion of this shaking the time shall be recorded, the graduate placed in the bath, and readings taken with the hydrometer at the end of both 1 and 2 min. The hydrometer shall be read at the top of the meniscus formed by the suspension around its stem. If hydrometer *A* is used, it shall be read to the nearest ½ g. per liter. Hydrometer ***B*** shall be read to the nearest 0.0005 specific gravity. Subsequent readings shall be taken at intervals of 5, 15, 30, 60, 250 and 1440 min. after the beginning of sedimentation. Readings on the thermometer placed in the constant temperature bath shall be made coincidentally with the hydrometer readings and recorded.

(*c*) After each reading except the 1-min. reading, the hydrometer shall be very carefully removed from the soil suspension in such a manner as to cause no disturbance in the suspension, wiped clean, and laid aside. About 15 or 20 sec. before the time for a reading it shall again be slowly and carefully placed in the soil suspension. The reading shall not be taken until the hydrometer has come to rest.

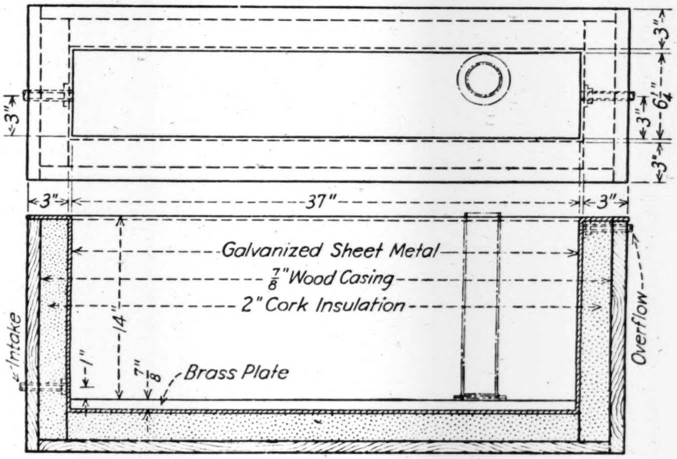

FIG. 5.—Insulated Water Bath.

SIEVE ANALYSIS

Sieve Analysis

7. At the conclusion of the final reading the suspension shall be washed on a No. 200 sieve. That fraction retained on the No. 200 sieve shall be dried and then analyzed in a nest of sieves consisting of one each of the following: Nos. 20, 40, 60, 140 and 200.

CALCULATIONS

Hygroscopic Moisture

8. The hygroscopic moisture shall be expressed as a percentage of the weight of the oven-dried soil and shall be determined by the following formula:

$$\text{Hygroscopic moisture} = \frac{\text{weight of air-dried soil} - \text{weight of oven-dried soil}}{\text{weight of oven-dried soil}} \times 100$$

To correct the weight of the air-dried sample for hygroscopic moisture the given value shall be multiplied by the expression:

$$\frac{100}{100 + \text{percentage of hygroscopic moisture}}$$

Coarse Material

9. (*a*) The percentage of coarse material shall be obtained from the data recorded during the preparation of the sample in accordance with the Tentative Method of Preparing Soil Sample as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 38 T) of the American Society for Testing Materials.[1]

(*b*) The coarse material shall be determined as follows: From the weight of the air-dried total test sample subtract the weight of the oven-dried fraction retained on the No. 10 sieve. The difference is assumed to equal the weight of the air-dried fraction passing the No. 10 sieve. According to this assumption, no hygroscopic moisture is contained in the air-dried particles retained on the No. 10 sieve, when as a matter of fact a small percentage of moisture may be present in this fraction. This amount of moisture, compared with that held in the pores of the fraction passing the No. 10 sieve, is relatively small. Therefore, any error produced by the assumption as stated may be considered negligible in amount. The weight of the fraction passing the No. 10 sieve shall be corrected for hygroscopic moisture as indicated in Section 8. To this value add the weight of the oven-dried fraction retained on the No. 10 sieve to obtain the weight of the total test sample corrected for hygroscopic moisture. The fractions retained on both the No. 4 and the No. 10 sieve shall be expressed as percentages of the corrected weight of the total test sample.

Example.—The following illustration is an example of the data used in calculating the hygroscopic moisture and percentage of coarse material:

Hygroscopic Moisture

Weight of air-dried soil, g	15.00
Weight of oven-dried soil, g	14.63
Hygroscopic moisture, percentage of weight of oven-dried soil	2.53
Hygroscopic moisture correction factor	0.975

Coarse Material

Weight of total test sample, air-dried, g	318.3
Weight of washed and oven-dried fraction retained on No. 10 sieve, g	56.2
Weight of fraction passing No. 10 sieve, air-dried, g	262.1
Weight of fraction passing No. 10 sieve corrected for hygroscopic moisture, g	255.5
Weight of total test sample corrected for hygroscopic moisture, g	311.7
Weight of fraction retained on No. 4 sieve, oven-dried, g	40.6
Fraction retained on No. 4 sieve, percentage of corrected weight of total test sample	13.0
Fraction retained on No. 10 sieve, percentage of corrected weight of total test sample	18.0

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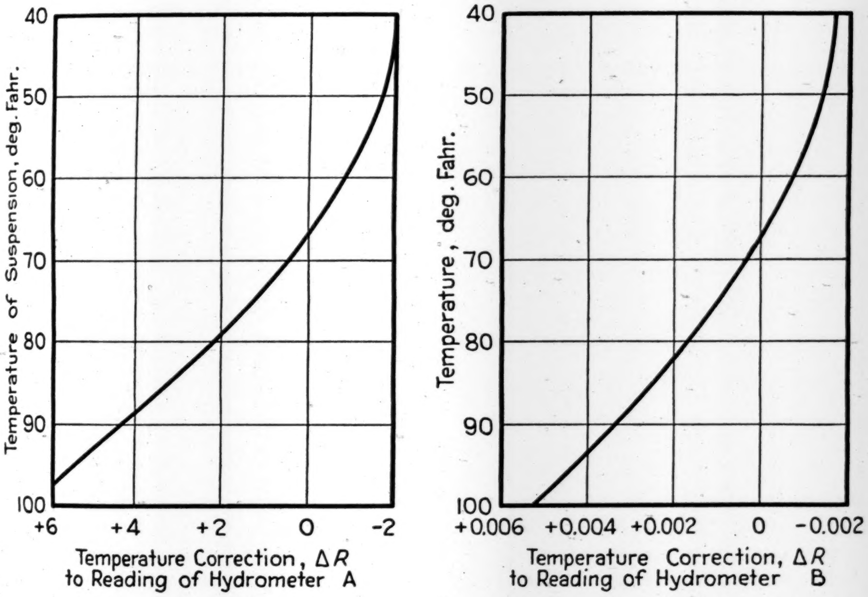
[1] See p. 942.

Percentage of Soil in Suspension

10. (*a*) For temperatures of the constant temperature bath other than that at which the hydrometers were calibrated, the readings of hydrometer *A* shall be corrected by adding temperature-correction factors such as are shown graphically as Δ R in Fig. 6 (*a*). A temperature-correction curve of this type should be determined experimentally for each hydrometer of type *A* used.



(a) (b)

FIG. 6.—Temperature-Correction Curves for Hydrometer Readings.

(*b*) Readings of hydrometer *B* shall be corrected by adding temperature-correction factors shown as Δ R in Fig. 6 (*b*). The temperature-correction curve for hydrometer *B* is determined by plotting the differences between the density of water at the various temperatures and that at 67 F. (19.4 C.) against temperatures from 40 to 100 F. (4.4 to 37.8 C.).

(*c*) The percentage of the dispersed soil in suspension represented by different corrected hydrometer readings depends upon both the amount and the specific gravity of the soil dispersed. The percentage of dispersed soil remaining in suspension may be obtained from the following formulas:

$$\text{For hydrometer } A\text{: } P = \frac{Ra}{W} \times 100$$

$$\text{For hydrometer } B\text{: } P = \frac{1606\ (R-1)a}{W} \times 100$$

where P = the percentage of originally dispersed soil remaining in suspension

R = the corrected hydrometer reading

W = the weight in grams, of soil originally dispersed minus the hygroscopic moisture

a = constant depending on the density of the suspension

For hydrometer A, the value of a, for a specific gravity G and a water density at 67 F. (19.4 C.) of 0.9984, may be obtained from the following formula:

$$a = \frac{2.6500 - 0.9984}{2.6500} \times \frac{G}{G - 0.9984}$$

For hydrometer B, the value of a for an assumed density of 1.0000 at 67 F. (19.4 C.) may be obtained from the following formula:

$$a = \frac{2.6500 - 1.0000}{2.6500} \times \frac{G}{G - 1.0000}$$

The values of a given by the two equations for different values of the specific gravity of soil G, are the same to two decimal places, and are as follows:

Specific Gravity, G	Constant, a
2.95	0.94
2.85	0.96
2.75	0.98
2.65	1.00
2.55	1.02
2.45	1.05
2.35	1.08

It is sufficiently accurate for ordinary tests to select the constant for the specific gravity nearest to that of the particular soil tested.

Example.—Assume that the weight of dispersed soil corrected for hygroscopic moisture is 48.5 g., the uncorrected reading of hydrometer A is 34, the specific gravity 2.41, and the temperature of suspension 70 F. (21 C.). The temperature correction is then +0.4 (Fig. 6 (*a*)) and the corrected reading, R, is $34 + 0.4 = 34.4$. The specific gravity correction, a, is 1.05.

$$\text{Then } P = \frac{34.4 \times 1.05}{48.5} \times 100 = 74.5.$$

(*d*) The percentage of the total test sample, including the fraction retained on the No. 10 sieve, shall be obtained by multiplying the percentage of originally dispersed soil remaining in suspension by the expression:

$$\frac{100 - \text{percentage retained on the No. 10 sieve}}{100}$$

Diameter of Soil Particles in Suspension

11. (*a*) The maximum diameter of the particles in suspension, corresponding to the percentage indicated by a given hydrometer reading, shall be as indicated by Stokes' law.

$$\text{According to Stokes' law: } d = \sqrt{\frac{30nL}{980\,(G - G_1)\,T}}$$

where d = the maximum grain diameter in millimeters

n = the coefficient of viscosity of the suspending medium (in this case water) in poises. Varies with changes in temperature of the suspending medium.

L = the distance in centimeters through which soil particles settle in a given period of time

T = the time in minutes, period of sedimentation

G = the specific gravity of soil particles

G_1 = the specific gravity of the suspending medium. In this case $G_1 = 0.9984$, or approximately 1.0

(*b*) The maximum grain diameters in suspension for assumed conditions and corresponding to the periods of sedimentation specified in this procedure are given in Table I. These grain diameters shall be corrected for the conditions of the test by applying the proper correction factors as described and explained below.

TABLE I.—MAXIMUM GRAIN DIAMETERS IN SUSPENSION UNDER ASSUMED CONDITIONS.

TIME, MIN.	MAXIMUM GRAIN DIAMETER IN SUSPENSION, MM.
1	0.078
2	0.055
5	0.035
15	0.020
30	0.014
60	0.010
250	0.005
1440	0.002

(*c*) The grain diameters given in Table I are calculated according to the following assumptions:

L, the distance through which the particles fall, is constant and equal to 32.5 cm.

n, the coefficient of viscosity, equals 0.0102, that of water at 67 F. (19.4 C.).[1]

G, the specific gravity of the soil particles, is constant and equal to 2.65.

NOTE.—As a matter of fact, the hydrometer reading is dependent, not on the particles distributed throughout a depth of 32.5 cm. in the suspension, but on those existing in that portion of the suspension holding the hydrometer.

(*d*) In order to use Stokes' law to determine the diameter of the particles it is necessary to know the distance through which these particles fall in a given time. Since the density throughout a suspension is not uniform and varies with the grading of the material in suspension and the time of sedimentation, a fixed distance cannot be used. For hydrometer *B* the depth of the center of volume of the hydrometer below the surface of

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[1] *Smithsonian Physical Tables*, 7th revised edition, 1921, p. 155.

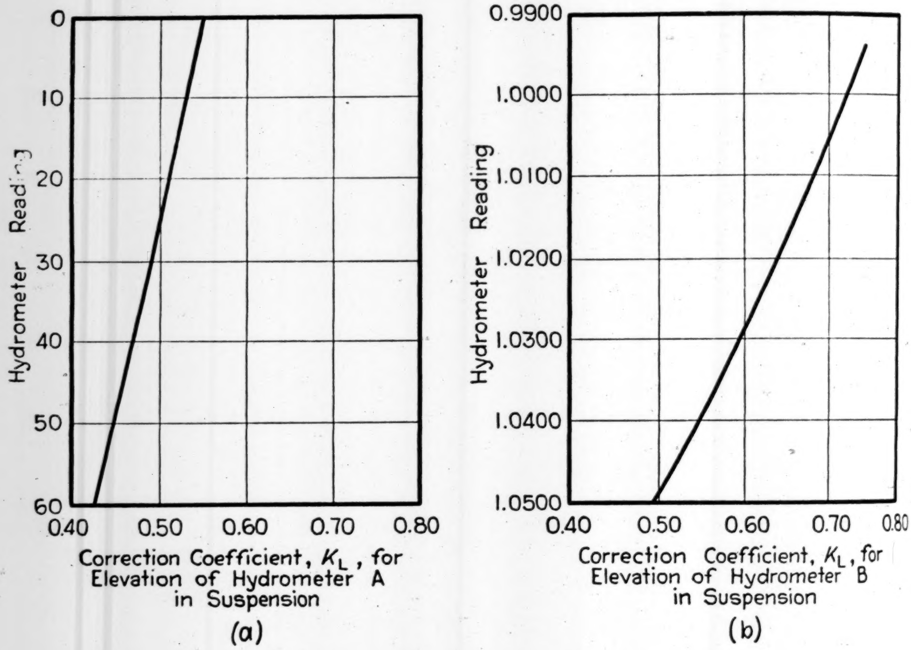

FIG. 7.—Correction Coefficient Curves for Elevation of Hydrometer.

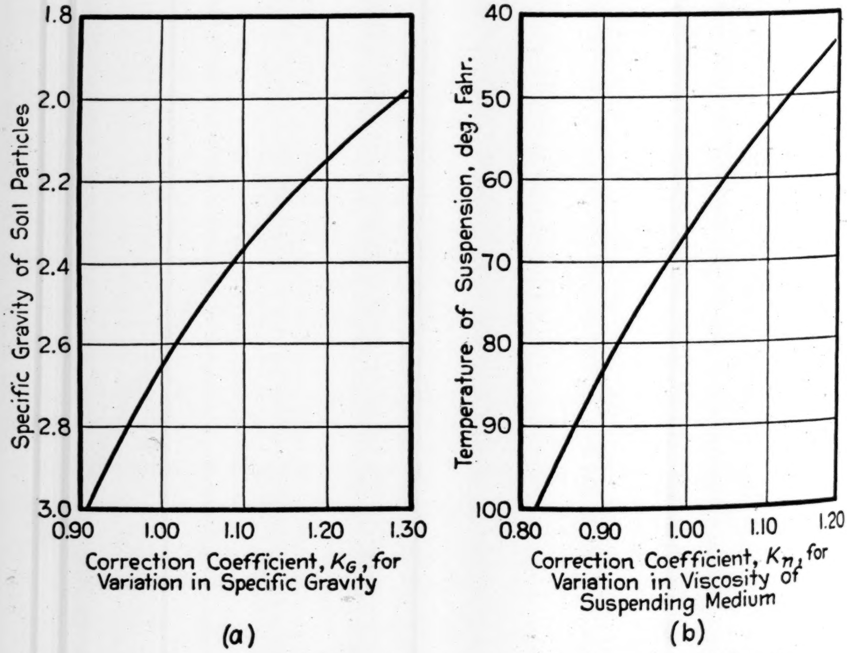

FIG. 8.—Correction Coefficient Curves for Specific Gravity and Viscosity.

the suspension can be taken as the distance through which the particles may be assumed to fall. In the case of hydrometer A, it has been found by experiment that for the methods of dispersion described in this procedure an assumed distance which bears a constant ratio to the depth of the hydrometer in the suspension, but which is less than the distance indicated by the center of volume of the hydrometer, gives closer agreement to mechanical analysis performed by the pipette methods. The assumed distance of fall is taken as 0.42 of the distance from the surface of the suspension to the elevation of the bottom of hydrometer A.

(*e*) The specific gravity of the soil particles and the temperature of the suspension are likely to vary from those assumed in the preparation of Table I. A better approximation of the true diameters of the soil particles is obtained by applying correction coefficients to the values given by Table I.

(*f*) Curves from which these coefficients may be derived are given in Figs. 7 and 8. The correction coefficients for elevation of hydrometer (Fig. 7 (*a*) and (*b*)) are obtained experimentally for each hydrometer in use. The coefficients for the specific gravity and the viscosity correction (Fig. 8 (*a*) and (*b*), respectively) are independent of the apparatus used in the test.

(*g*) Multiplication by the coefficients shown in Fig. 7 (*a*) and (*b*) gives the maximum grain size at the reference elevation of hydrometers A and B, respectively, instead of that at a depth of 32.5 cm. These coefficients vary with the hydrometer reading and may be obtained from the following formula:

$$K_L = \sqrt{\frac{\text{assumed depth of fall in centimeters}}{32.5}}$$

(*h*) Multiplication by the coefficients shown in Fig. 8 (*a*) corrects for variation in specific gravity from that on which the sizes given in Table I are based. These coefficients may be obtained from the following formula:

$$K_G = \sqrt{\frac{1.65}{\text{specific gravity of soil particle} - 1}}$$

(*i*) Multiplication by the coefficients shown in Fig. 8 (*b*) corrects for the viscosity of water at temperatures other than 67 F. (19.4 C.), the temperature of the suspension assumed in the preparation of Table I. The viscosity correction coefficient may be obtained from the following formula:

$$K_n = \sqrt{\frac{\text{viscosity coefficient at given temperature}}{0.0102}}$$

Example.—After a period of sedimentation of 1 min. the grain diameter indicated by Table I is 0.078 mm. Assume that the uncorrected reading of hydrometer A is 34, the specific gravity is 2.41, and the temperature of the suspension is 70 F. (21 C.). The correction coefficients in this case are 0.48, corresponding to a hydrometer reading of 34 (Fig. 7 (*a*)); 1.08, corresponding to a specific gravity of 2.41 (Fig. 8 (*a*)); and 0.98, corresponding to a water temperature of 70 F. (21 C.) (Fig. 8 (*b*)). The corrected grain diameter then becomes:

$$0.078 \text{ mm.} \times 0.48 \times 1.08 \times 0.98 = 0.040 \text{ mm.}$$

Sieve Analysis

12. (*a*) The percentage of the dispersed soil sample retained on each of the sieves in the sieve analysis shall be obtained by dividing the weight of fraction retained on each sieve by the oven-dry weight of the dispersed soil and multiplying by 100.

(*b*) The percentages of the total test sample, including the fraction retained on the No. 10 sieve, shall be obtained by multiplying these values by the expression:

$$\frac{100 - \text{percentage retained on the No. 10 sieve}}{100}$$

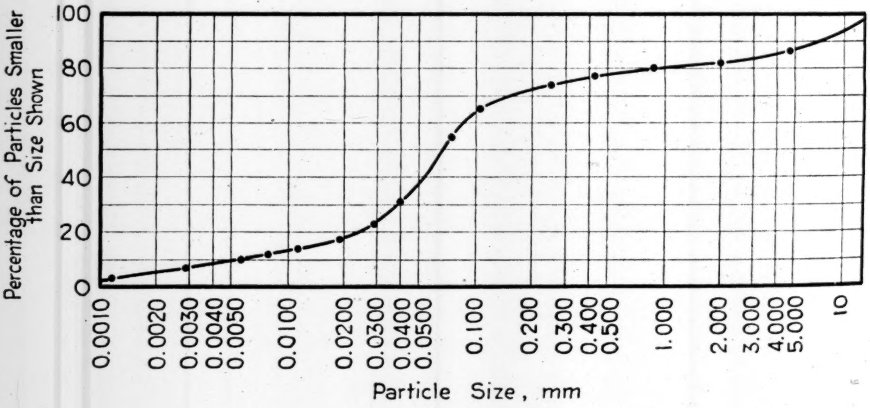

FIG. 9.—Grain Size Accumulation Curve, Soil Sample No. 4422X.

Plotting

13. The percentages of grains of different grain diameters shall be plotted on semilogarithmic paper to obtain a "soil grain diameter accumulation curve." A curve of this character is shown in Fig. 9.

Report

14. The results, read from the accumulation curve, shall be reported as follows:

(*a*) Percentage of particles larger than 2 mm.
(*b*) Percentage of coarse sand, 2.0 to 0.25 mm.
(*c*) Percentage of fine sand, 0.25 to 0.05 mm.
(*d*) Percentage of silt, 0.05 to 0.005 mm.
(*e*) Percentage of clay, smaller than 0.005 mm.
(*f*) Percentage of colloids, smaller than 0.001 mm.

TENTATIVE METHOD OF TEST
FOR
PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS[1]

A.S.T.M. Designation: D 424 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

Plastic Limit

1. The plastic limit of a soil is the lowest moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil can be rolled into threads $\frac{1}{8}$ in. in diameter without the threads breaking into pieces.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish.*—A porcelain evaporating dish about $4\frac{1}{2}$ in. in diameter.

(*b*) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about $\frac{3}{4}$ in. in width.

(*c*) *Surface for Rolling.*—A ground-glass plate or piece of rough-textured paper on which to roll the sample.

(*d*) *Containers.*—Suitable containers such as matched watch glasses which will prevent loss of moisture during weighing.

(*e*) *Balance.*—A balance sensitive to 0.1 g.

Sample

3. A sample weighing about 15 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve, which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 38 T) of the American Society for Testing Materials.[2]

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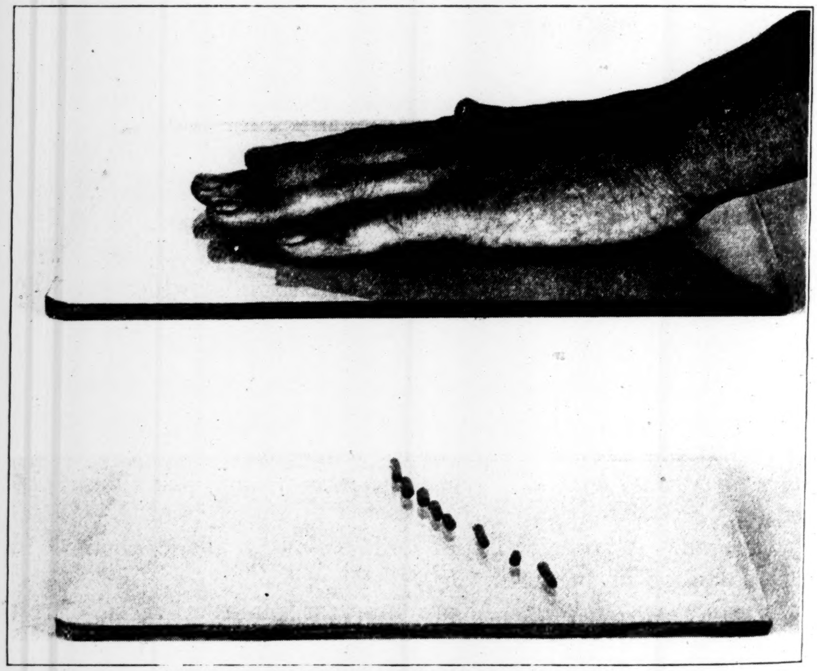
[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.

[2] See p. 942.

Procedure

4. The air-dried soil shall be placed in the evaporating dish and mixed with distilled water until the mass becomes plastic enough to be easily shaped into a ball. The ball of soil shall then be rolled between the palm of the hand and the ground-glass plate or piece of rough-textured paper with just sufficient pressure to form the soil mass into a thread (Fig. 1 (*a*)). When the diameter of the resulting thread becomes $\frac{1}{8}$ in. the soil shall be kneaded together and again rolled out. This process shall be continued until the crumbling of the soil (as shown in Fig. 1 (*b*)) prevents the formation of the thread. The portions of the crumbled soil shall then be gathered together and placed in watch glasses or other suitable containers. The container and soil shall be weighed and the weight recorded. The soil in the container shall then be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the loss in weight shall be recorded as the weight of water.

(*a*) Rolling of soil threads in plastic limit test.



(*b*) Crumbled soil threads resulting from plastic limit test.

FIG. 1.—Plastic Limit Test.

Calculation

5. The plastic limit is expressed as the moisture content in percentage of the weight of the oven-dry soil and shall be calculated by the following formula:

$$\text{Plastic limit} = \frac{\text{weight of water}}{\text{weight of oven-dry soil}} \times 100$$

Plasticity Index

6. The plasticity index of a soil is the difference between its liquid limit and its plastic limit.

7. The plasticity index shall be calculated by the following formula:

$$\text{Plasticity index} = \text{liquid limit} - \text{plastic limit}$$

NOTE.—Liquid limit shall be determined in accordance with the Tentative Method of Test for Liquid Limit of Soils (A.S.T.M. Designation: D 423 - 38 T) of the American Society for Testing Materials.[1]

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[1] See p. 949

TENTATIVE METHOD OF TEST
FOR
SHRINKAGE FACTORS OF SOILS[1]

A.S.T.M. Designation: D 427 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935; Revised, 1938.

Scope

1. This method furnishes the data from which the following subgrade soil constants may be calculated:

Shrinkage Limit
Shrinkage Ratio
Volumetric Change
Lineal Shrinkage
Specific Gravity (Approximate)

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish.*—A porcelain evaporating dish about $4\frac{1}{2}$ in. in diameter.

(*b*) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about $\frac{3}{4}$ in. in width.

(*c*) *Shrinkage Dish.*—A circular porcelain or monel metal milk dish having a flat bottom and being about $1\frac{3}{4}$ in. in diameter and about $\frac{1}{2}$ in. in height.

(*d*) *Straight Edge.*—A steel straight edge about 12 in. in length.

(*e*) *Glass Cup.*—A glass cup about 2 in. in diameter and about 1 in. in height, the top rim of which is ground smooth and level.

(*f*) *Glass Plate.*—A glass plate with three metal prongs for immersing the soil pat in mercury, as shown in Fig. 1.

(*g*) *Graduate.*—A glass graduate having a capacity of 25 cc. and graduated to 0.2 cc.

(*h*) *Balance.*—A balance sensitive to 0.1 g.

(*i*) *Mercury.*—Sufficient mercury to fill the glass cup to overflowing.

Sample

3. A sample weighing about 30 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve which has been

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[1] **Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-18 on Soils for Engineering Purposes.**

obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 38 T) of the American Society for Testing Materials.[1]

Procedure

4. (*a*) The sample shall be placed in the evaporating dish and thoroughly mixed with distilled water in amount sufficient to fill the soil voids completely and to make the soil pasty enough to be readily worked into the porcelain milk dish without the inclusion of air bubbles. The amount of water required to furnish friable soils with the desired consistency is equal to or slightly greater than the liquid limit, and the amount necessary to furnish plastic soils with the desired consistency may exceed the liquid limit by as much as 10 per cent.

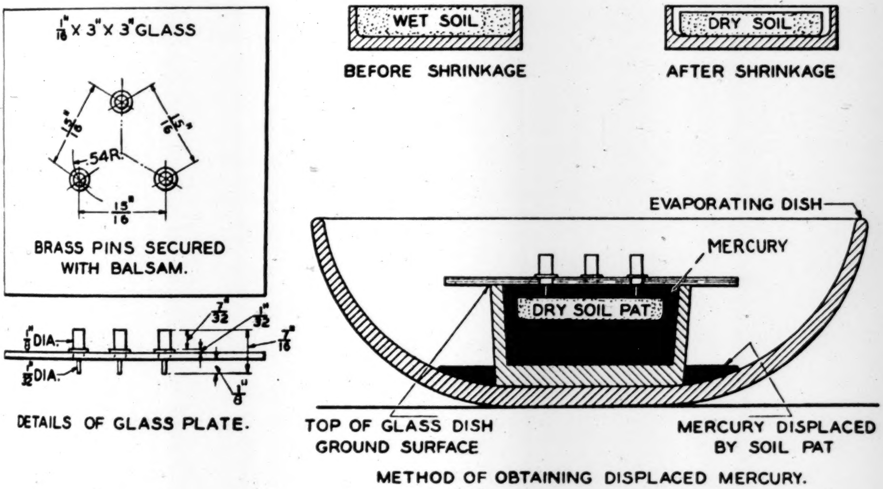
1/16" X 3" X 3" GLASS
.54R.
15/16"
15/16"
15/16"
BRASS PINS SECURED WITH BALSAM.
1/8" DIA.
3/32" DIA.
7/32"
1/32"
7/16"
1/8"
DETAILS OF GLASS PLATE.
WET SOIL
BEFORE SHRINKAGE
DRY SOIL
AFTER SHRINKAGE
EVAPORATING DISH
MERCURY
DRY SOIL PAT
TOP OF GLASS DISH GROUND SURFACE
MERCURY DISPLACED BY SOIL PAT
METHOD OF OBTAINING DISPLACED MERCURY.

Fig. 1.—Apparatus for Determining the Volumetric Change of Subgrade Soils.

(*b*) The inside of the porcelain milk dish shall be coated with a thin layer of vaseline or some other heavy grease to prevent the adhesion of the soil to the dish. An amount of the wetted soil equal to about one-third the volume of the milk dish shall be placed in the center of the dish, and the soil caused to flow to the edges by tapping the dish on a firm surface cushioned by several layers of blotting paper or similar material. An amount of soil shall be added approximately equal to the first portion, and the dish tapped until the soil is thoroughly compacted and all included air has been brought to the surface. More soil shall be added and the tapping shall be continued until the dish is completely filled and excess soil stands out about its edge. The excess soil shall then be struck off with a straight edge, and all soil adhering to the outside of the dish shall be wiped off.

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[1] See p. 942.

(*c*) The dish when filled and struck off shall be weighed immediately and the weight recorded as the weight of dish and wet soil. The soil pat shall be allowed to dry in air until the color of the pat turns from dark to light. It shall then be oven-dried to constant weight at 110 C. and weighed, the weight being recorded as the weight of dish and dry soil. The weight of the empty dish shall be determined and recorded. The capacity of the dish in cubic centimeters, which is also the volume of the wet soil pat, shall be determined by filling the dish to overflowing with mercury, removing the excess by pressing a glass plate firmly over the top of the dish, and measuring by means of a glass graduate the volume of mercury held in the dish. This volume shall be recorded as the volume of the wet soil pat, V.

(*d*) The volume of the dry soil pat shall be determined by removing the pat from the porcelain milk dish and immersing it in the glass cup full of mercury in the following manner: The glass cup shall be filled to overflowing with mercury and the excess mercury shall be removed by pressing the glass plate with the three prongs (Fig. 1) firmly over the top of the cup. Any mercury which may be adhering to the outside of the cup shall be carefully wiped off. The cup, filled with mercury, shall be placed in the evaporating dish, and the soil pat shall be placed on the surface of the mercury. It shall then be carefully forced under the mercury by means of the glass plate with the three prongs (Fig. 1) and the plate shall be pressed firmly over the top of the cup. It is essential that no air be trapped under the soil pat. The volume of the mercury so displaced shall be measured in the glass graduate and recorded as the volume of the dry soil pat, V_o).

Calculation of Moisture Content

5. The moisture content of the soil at the time it was placed in the dish expressed as a percentage of the dry weight of the soil shall be calculated from the formula:

$$w = \frac{W - W_o}{W_o} \times 100$$

where w = the moisture content of the soil when placed in the dish.

W = the weight of the wet soil pat obtained by subtracting the weight of the porcelain milk dish from the weight of the dish and wet pat.

W_o = the weight of the dry soil pat obtained by subtracting the weight of the porcelain milk dish from the weight of the dish and dry pat.

Shrinkage Limit

6. The shrinkage limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which a reduction in

moisture content will not cause a decrease in the volume of the soil mass, but at which an increase in moisture content will cause an increase in the volume of the soil mass.

Calculation of Shrinkage Limit

7. (*a*) The shrinkage limit, S, shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$S = w - \left(\frac{V - V_o}{W_o} \times 100\right)$$

where S = the shrinkage limit
w = the moisture content of the wet soil, in percentage of the weight of oven-dried soil
V = the volume of wet soil pat
V_o = the volume of dry soil pat
W_o = the weight of oven-dried soil pat.

(*b*) *Optional Method.*—When both the true specific gravity, G, and the shrinkage ratio, R, are known, the shrinkage limit may be calculated from the following formula:

$$S = \left(\frac{1}{R} - \frac{1}{G}\right) \times 100$$

Shrinkage Ratio

8. The shrinkage ratio of a soil is the ratio between a given volume change, expressed as a percentage of the dry volume, and the corresponding change in moisture content above the shrinkage limit, expressed as a percentage of the weight of the oven-dried soil. It equals the apparent specific gravity of the dried soil pat.

Calculation of Shrinkage Ratio

9. The shrinkage ratio, R, shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$R = \frac{W_o}{V_o}$$

Volumetric Change

10. The volumetric change of a soil for a given moisture content is the volume change, expressed as a percentage of the dry volume, of the soil mass when the moisture content is reduced from the stipulated percentage to the shrinkage limit. This stipulated moisture content is usually taken as the field moisture equivalent.

Calculation of Volumetric Change

11. The volumetric change shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$\text{Volumetric change} = (w_1 - S)R$$

where w_1 = the given moisture content

If, as is customary, the volumetric change from the field moisture equivalent is desired, the formula assumes the following form:

Volumetric change, C_f = volumetric change from field moisture equivalent
Volumetric change = (field moisture equivalent $- S)R$

Lineal Shrinkage

12. The lineal shrinkage of a soil for a given moisture content is the decrease in one dimension, expressed as a percentage of the original dimension, of the soil mass when the moisture content is reduced from an amount equal to the field moisture equivalent to the shrinkage limit.

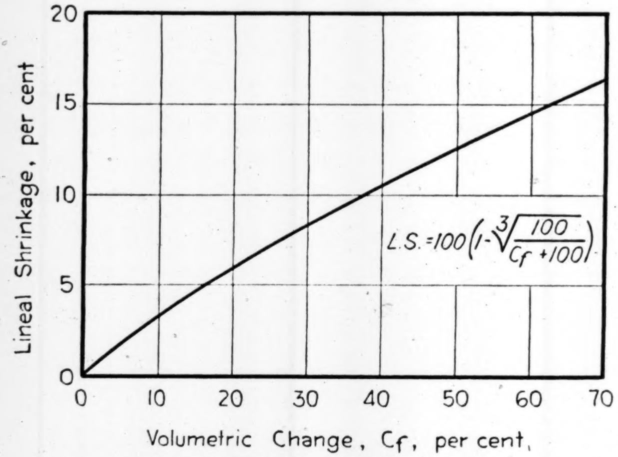

FIG. 2.—Curve for Determining Lineal Shrinkage.

Calculation of Lineal Shrinkage

13. The lineal shrinkage shall be obtained either by means of the following formula or by means of the curve shown in Fig. 2, which represents this relation:

$$\text{Lineal shrinkage} = 100\left(1 - \sqrt[3]{\frac{100}{C_f + 100}}\right)$$

Specific Gravity

14. The specific gravity of a soil is the weight of the oven-dried soil divided by the true volume of the soil particles.

Calculation of Specific Gravity

15. The specific gravity may be calculated from the data obtained in the volumetric shrinkage test by the following formula:

$$\text{Sp. Gr.} = \frac{1}{\frac{1}{R} - \frac{S}{100}}$$

TENTATIVE SPECIFICATIONS
FOR
ASPHALT MASTIC FOR USE IN WATERPROOFING[1]
(ASPHALT CEMENT, MINERAL FILLER, MINERAL AGGREGATE)

A.S.T.M. Designation: D 491 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

1. These specifications cover asphalt mastic, consisting of asphalt cement, mineral filler and mineral aggregate, suitable for use in waterproofing the floors of buildings and bridges, reservoirs, waterways, subways, and similar structures.

Character of Mastic

2. (*a*) The asphalt mastic shall consist of a mixture of asphalt cement, mineral filler, sand and gravel, which, at a temperature of approximately 400 F. (205 C.), shall be sufficiently plastic to be poured into place and compressed with a wooden trowel or by other suitable means into a compact, watertight sheet of the thickness desired.

(*b*) The raw materials for the asphalt mastic are expected to be mixed on the site of the work, in either suitable mechanically operated heaters and mixers, or by manual stirring in open pans or kettles. The mixture so prepared, shall be applied to the work or performed for application to the work while it is sufficiently hot to be manipulated with hand tools or by other equivalent means.

Properties of Asphalt Cement

3. The asphalt cement used in the asphalt mastic shall conform to the following requirements:

	Minimum	Maximum
(*a*) Softening point (ring-and-ball method)	130 F. (57 C.)	150 F. (66 C.)
(*b*) Penetration at 77 F. (25 C.), 100 g., 5 sec	20	40
(*c*) Ductility at 77 F. (25 C.) (5 cm. per min.), cm	15	..
(*d*) Loss on heating at 325 F. (163 C.), 50 g., 5 hr., per cent	..	2
(*e*) Penetration of residue at 77 F. (25 C.), per cent of original	60	..
(*f*) Bitumen soluble in carbon disulfide:		
Filled or native asphalt cement, per cent	60	..
Unfilled asphalt cement, per cent	99	..
(*g*) Bitumen soluble in carbon tetrachloride, per cent	99	..
(*h*) Ash:		
Filled or native asphalt cement, per cent	7.5	35
Unfilled asphalt cement, per cent	..	1
(*i*) Coarse particles retained on No. 200 sieve as percentage of ash	..	12

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

Properties of Asphalt Mastic

4. (*a*) The asphalt mastic shall conform to the following requirements by weight, as determined by laboratory analysis:

	MINIMUM	MAXIMUM
Bituminous matter soluble in pure benzol, per cent...	10	12
Mineral filler insoluble in benzol, passing a No. 200 sieve, per cent....	18	25
Mineral aggregate:		
Passing a No. 40 and retained on a No. 200 sieve, per cent....	20	30
Passing a No. 10 and retained on a No. 40 sieve, per cent....	10	15
Passing a No. 4 and retained on a No. 10 sieve, per cent....	5	15
Passing a No. 2 and retained on a No. 4 sieve, per cent....	15	25

(*b*) The portion of asphalt mastic which is soluble in pure benzol shall, after extraction and recovery, conform to the following requirements:

	MINIMUM	MAXIMUM
Penetration at 77 F. (25 C.), 100 g., 5 sec....	15	35
Softening point (ring-and-ball method)....	122 F. (50 C.)	158 F. (70 C.)
Ductility at 77 F. (25 C.) (5 cm. per min.), cm....	15	..

(*c*) That portion of asphalt mastic, when designated as acid resisting, which is insoluble in benzol shall conform to the following requirement:

Matter soluble in diluted HCl................................not more than 5 per cent

Methods of Testing

5. The properties enumerated in these specifications, with the exception of the method for recovery and preparation for test of bituminous matter soluble in pure benzol[1] (Section 4 (*b*)), shall be determined in accordance with the Standard Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (A.S.T.M. Designation: D 147) of the American Society for Testing Materials.[2]

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[1] Until standard methods are available, recovery and preparation for test of the bituminous matter soluble in pure benzol shall be made according to the "Method and Apparatus for the Recovery of Asphalt," as described in the paper by Gene Abson, see *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 704 (1933).

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1143.

TENTATIVE SPECIFICATIONS
FOR
COAL-TAR PITCH FOR ROOFING, DAMP-PROOFING AND WATERPROOFING[1]

A.S.T.M. Designation: D 450 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. These specifications cover coal-tar pitch suitable for use as a mopping coat in the construction of built-up roofs surfaced with slag or gravel, as a mopping coat in damp-proofing, or as a plying or mopping cement in the construction of a membrane system of waterproofing.

Primer

2. The material used as a primer shall be creosote conforming to the Tentative Specifications for Creosote for Priming Coat with Coal-Tar Pitch in Damp-proofing and Waterproofing (A.S.T.M. Designation: D 43 – 37 T) of the American Society for Testing Materials.[2]

Membrane Materials

3. For the construction of built-up roofs, felts conforming to the Standard Specifications for Coal-Tar Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (A.S.T.M. Designation: D 227) of the American Society for Testing Materials[3] shall be used.

4. For the construction of a membrane system of waterproofing, any or all of the following felts, fabrics, or burlap conforming to the specifications of the American Society for Testing Materials may be used alone or in various combinations:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These tentative specifications are in effect a revision of, and replace the former Tentative Specifications for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (D 42 – 36 T), for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level (D 145 - 36 T), for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level (D 200 – 36 T), for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level (D 201 – 36 T), for High-Carbon Coal-Tar Pitch for Use in Constructing Built-Up Roofs Surfaced with Slag or Gravel (D 251 – 36 T), and for High-Bitumen Coal-Tar Pitch for Use in Constructing Built-Up Roofs Surfaced with Slag or Gravel (D 252 – 36 T), which specifications were accordingly discontinued in 1937.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 951 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1014.

[3] 1936 Book of A.S.T.M. Standards, Part II, p. 1140.

(*a*) Standard Specifications for Coal-Tar Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (A.S.T.M. Designation: D 227).[1]

(*b*) Tentative Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (A.S.T.M. Designation: D 173),[2] coal-tar saturant.

Types of Pitch

5. The coal-tar pitches covered by these specifications are of two types, as follows:

Type A.—Coal-tar pitch for use as a mopping coat in the construction of built-up roofs surfaced with slag or gravel on inclines not exceeding 3 in. per ft. where nailing is employed, and not exceeding 1 in. per ft. where nailing is omitted.

Coal-tar pitch for use as a mopping coat in damp-proofing or as a plying cement in the construction of a membrane system of waterproofing above ground level when not exposed to temperatures exceeding 125 F. (52 C.).

NOTE.—This type of coal-tar pitch is suitable for railroad bridges, tanks, retaining walls, culverts, dams, conduits, etc.

Type B.—Coal-tar pitch for use as a mopping coat in damp-proofing or as a plying cement in the construction of a membrane system of waterproofing below ground level under uniformly moderate temperature conditions both during the process of installation and during service.

Properties

6. The coal-tar pitch shall be homogenous and shall conform to the following requirements:

	MIN.	MAX.
(*a*) Water, per cent	....	0
(*b*) Specific gravity at 25/25 C. (77/77 F.)	1.22	1.34
(*c*) Softening point (cube-in-water method):		
Type A	140 F. (60 C.)	155 F. (68 C.)
Type B	120 F. (49 C.)	140 F. (60 C.)
(*d*) Distillation test:		
Total distillate by weight 32 to 572 F. (0 to 300 C.), per cent	....	10
Residue by weight, per cent	90	....
(*e*) Specific gravity at 100/60 F. (38/15.5 C.) of total distillate to 572 F. (300 C.)	1.03	....
(*f*) Softening point (cube-in-water method) of residue from distillation to 572 F. (300 C.)	....	175 F. (79 C.)
(*g*) Ductility at 25 C. (77 F.) (5 cm. per min.), cm.	50	....
(*h*) Total bitumen soluble in carbon disulfide, per cent	72	85
(*i*) Ash, per cent	....	0.5
(*j*) Flash point (Cleveland open cup)	248 F. (120 C.)	....

NOTE.—The usual range for softening point of roofing pitch shall be 140 to 150 F. In hot summer weather a softening point range of 145 to 155 F. will be permitted.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1140.

[2] See p. 980.

Methods of Sampling and Testing

7. The coal-tar pitch shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140).[1]

(*b*) *Water.*—Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (A.S.T.M. Designation: D 95).[2]

(*c*) *Specific Gravity.*—Standard Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (A.S.T.M. Designation: D 70).[3]

(*d*) *Softening Point.*—Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (A.S.T.M. Designation: D 61).[4]

(*e*) *Distillation.*—Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (A.S.T.M. Designation: D 20).[5]

(*f*) *Ductility.*—Standard Method of Test for Ductility of Bituminous Materials (A.S.T.M. Designation: D 113).[6]

(*g*) *Total Bitumen (Soluble in Carbon Disulfide).*—Standard Method of Test for the Determination of Bitumen (A.S.T.M. Designation: D 4).[7]

(*h*) *Ash.*—Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271).[8]

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1088.
[2] *Ibid.*, p. 997.
[3] *Ibid.*, p. 1110.
[4] 1938 Supplement to Book of A.S.T.M. Standards, p. 153.
[5] 1936 Book of A.S.T.M. Standards, Part II, p. 1053.
[6] *Ibid.*, p. 1058.
[7] *Ibid.*, p. 1041.
[8] 1937 Supplement to Book of A.S.T.M. Standards, p. 153.

Tentative Specifications for

ASPHALT-SATURATED ROOFING FELT FOR USE IN WATERPROOFING AND IN CONSTRUCTING BUILT-UP ROOFS[1]

A.S.T.M. Designation: D 226 - 38 T

ISSUED AS TENTATIVE, 1925; ADOPTED IN AMENDED FORM, 1927; REVISED AND REISSUED AS TENTATIVE, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover asphalt-saturated felt, either 36 or 32 in. in width, composed of roofing felt saturated, but not coated, with asphalt for use in the membrane system of waterproofing and in the construction of built-up roofs.

Types

2. Asphalt-saturated felts covered by these specifications are of two types: namely,

15-lb. Type
30-lb. Type

Manufacture

3. In the process of manufacture, a single thickness of dry roofing felt shall be saturated with an asphaltic saturant.

Character of Felt

4. The felt shall be a roofing felt produced by "felting" vegetable and animal fibers. The surface of the felt shall be uniformly smooth and, upon splitting or tearing on the bias, shall appear reasonably free from lumps of underbeaten stock (that is, stock which has not been beaten or shredded into fiber in the process of manufacture) and particles of foreign substances (that is, fragments of stone, metal, leather, rubber, straw, wood, etc.).

Character of Saturant

5. The saturant shall be composed of asphaltic materials.

Physical Properties

6. The fabricated bituminized felt shall conform to the following requirements:

	15-LB. TYPE	30-LB. TYPE
(*a*) Width of roll	either 36 or 32 as may be specified ±¼ in.	
(*b*) Area of roll, min., sq. ft.	432	216
(*c*) Minimum weight of saturated felt per 100 sq. ft. (exclusive of wrapping and packing material), lb.	14	29

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These specifications are in effect a revision of, and replace the former Standard Specifications for Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (D 226 - 27), which specifications were accordingly discontinued in 1938.

	15-LB. TYPE	30-LB. TYPE
(*d*) Loss on heating at 105 C. (221 F.) for 5 hr., max., per cent	4	4
(*e*) Pliability at 77 F. (25 C.): At least 8 strips out of 10 shall not crack when bent 90 deg. at a uniform speed over a rounded corner of	½ in. rad.	¾ in. rad.
(*f*) Average breaking strength:		
With fiber grains, min., lb.	30	40
Across fiber grains, min., lb.	15	20
(*g*) Saturant in moisture-free felt by weight, min., per cent	140	150

Surface Finish

7. The surface of the felt shall not be coated or covered with talc or other substance which would tend to interfere with the adhesion between the felt and the plying cement.

Saturation

8. The felt shall be thoroughly and uniformly saturated and shall show no unsaturated spots at any point upon cutting 2-in. strips at random across the entire sheet and splitting them open for their full length.

Desaturated Felt

9. The desaturated moisture-free felt shall conform to the following requirements:

	15-LB. TYPE	30-LB. TYPE
(*a*) Weight per 100 sq. ft., min., lb	5.2	10.0
(*b*) Ash, max., per cent	10	10

Freedom from Defects

10. The finished product shall be free from visible external defects, such as holes, ragged or untrue edges, breaks, cracks, tears, protuberances and indentations.

Pliability and Stickiness

11. The rolls shall not crack, or be so sticky as to cause tearing or material damage upon being unrolled at atmospheric temperatures above 50 F. (10 C.).

Packing

12. The rolls of saturated felt need not be wound on cores, but they shall be securely wrapped in a substantial grade of paper of the same width as the fabric. The wrapper shall completely encircle the roll and shall be pasted at the overlap in a manner which will prevent it shifting from position. The ends of the roll need not be covered. As an alternative, the rolls of saturated felt may either be tied with strings or simply pasted at the ends, as may be agreed upon by the purchaser and the seller. No roll shall contain more than two pieces, and there shall not be more than 3 per cent of rolls containing two pieces in any shipment.

Marking

13. Each roll shall be plainly marked with the manufacturer's name and brand or as agreed upon by the purchaser and the seller, and shall bear a notation showing the type of saturant.

Inspection

14. Inspection of material shall be made as mutually agreed upon by the purchaser and the seller as part of the purchase contract.

Sampling and Testing

15. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the Tentative Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing (A.S.T.M. Designation: D 146) of the American Society for Testing Materials.[2]

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[2] See p. 983.

TENTATIVE SPECIFICATIONS
FOR
WOVEN COTTON FABRICS SATURATED WITH BITUMINOUS SUBSTANCES FOR USE IN WATERPROOFING[1]

A.S.T.M. Designation: D 173 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1923; ADOPTED IN AMENDED FORM, 1925; REVISED, 1927; REVISED AND REISSUED AS TENTATIVE, 1938.

Scope.

1. These specifications cover bituminized cotton fabric, composed of woven cotton cloth waterproofed with either asphalt or coal-tar pitch, as specified by the purchaser, for use in the membrane system of waterproofing.

MANUFACTURE

Manufacture.

2. In the process of manufacture, the dry cotton fabric shall be thoroughly and uniformly waterproofed with an asphaltic or coal-tar pitch saturant, at a temperature and speed which will not injure the fabric. This shall be accomplished either by passing the fabric through the saturant or by spraying with saturant and then calendering it in the presence of heat, whereupon it shall be cooled and wound into rolls.

PHYSICAL PROPERTIES

Fabricated Bituminized Fabric.

3. The fabricated bituminized cotton fabric shall conform to the following requirements:

(*a*) The width shall be not less than 30 in. nor more than 38 in.

(*b*) The gross weight per roll shall fall within the range of 35 to 80 lb.

(*c*) The wrapping material and mandrel shall not weigh more than 2.5 lb. per roll.

(*d*) The average net weight per square yard shall not be less than 11 oz.

(*e*) The detached comminuted surfacing per 100 sq. ft. shall not weigh more than 1 lb.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These specifications are in effect a revision of, and replace the former Standard Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (D 173 – 27), which specifications were accordingly discontinued in 1938.

(*f*) The moisture content based on the net weight shall not be more than 4 per cent.

(*g*) The average strength at 70° F. (21.1° C.) measured lengthwise of the roll (that is, in the direction of the warp) shall not be less than 50 lb.[1]

(*h*) The average strength at 70° F. (21.1° C.) measured crosswise of the roll (that is, in the direction of the filling) shall not be less than 40 lb.[1]

(*i*) *Pliability ar 32 F. (0 C.).*—No cracking of the fabricated bituminized fabric shall take place on bending over a $\frac{1}{16}$-in. mandrel through an arc of 180 deg. in one direction and then through 360 deg. over the same mandrel in the opposite direction.

(*j*) The average loss on heating (exclusive of moisture) shall not be more than 4 per cent with asphalt-saturated fabrics.

(*k*) The weight of the saturant contained in the fabricated material shall not be less than 1.6 times the weight of the moisture-free fabric in the same area.

Desaturated Fabric.

4. The desaturated woven cotton fabric shall conform to the following requirements:

(*a*) The average dry weight shall not be less than 3½ oz. per sq. yd.

(*b*) The ash based on the dry weight of the fabric shall not be more than 1 per cent.

(*c*) The fabric shall be composed of not less than 100 per cent[2] of cotton fibers.

(*d*) The thread count per inch both in the direction of the warp and in the direction of the filling shall not be more than 36.

WORKMANSHIP AND FINISH

Finished Appearance.

5. The finished material shall be free from visible external defects such as ragged or untrue edges, breaks, rents or cracks.

Degree of Saturation.

6. The meshes of the fabric shall not be completely closed or sealed by the process of saturation, but there shall be sufficient porosity maintained to allow successive moppings of the plying cement to seep through.

Selvage.

7. The selvage shall not measure over $\frac{3}{16}$ in.

Stickiness.

8. The roll shall be capable of being unrolled easily at atmospheric temperatures above 50° F. (10° C.) without sticking together in such a manner as to injure the fabric.

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[1] The committee recognizes the advisability of including a requirement relative to the percentage elongation before rupture, but in the absence of any reliable method of test, such requirement cannot be stated at the present time.

[2] This shall not exclude the presence of the customary sizing materials in amounts not exceeding 8 per cent by weight of the moisture-free cotton.

Freedom from Talc. 9. The surface of the fabric shall not be coated or covered with talc or other substance which would tend to interfere with the adhesion between the fabric and the plying cement. The use of silica or wood flour will be permitted.

Finish. 10. The surface shall be uniformly smooth and free from irregularities, folds or knots.

PACKING

Packing. 11. The rolls of treated cotton fabric shall be wound on mandrels not less than 2 in. in diameter or 2 in. square, and extending not less than 2 in. nor more than 4 in. beyond the ends of the rolls. They shall be securely tied or wrapped in a manner which will prevent unrolling in transit.

SAMPLING AND TESTING

Sampling and Testing. 12. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the Tentative Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing (A.S.T.M. Designation: D 146) of the American Society for Testing Materials.[1]

INSPECTION

Inspection. 13. Inspection of material shall be made as agreed upon by the purchaser and seller as part of the purchase contract.

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[1] See p. 983.

TENTATIVE METHODS OF TESTING FELTED AND WOVEN FABRICS SATURATED WITH BITUMINOUS SUBSTANCES FOR USE IN WATERPROOFING AND ROOFING[1]

A.S.T.M. Designation: D 146 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1922; Adopted in Amended Form, 1927; Revised, 1937; Revised and Reissued as Tentative, 1938.

Scope. 1. These methods cover the examination of felted or woven fabrics saturated (but not coated) with asphalt or coal-tar products, for use in the "membrane" system of waterproofing.

SAMPLING

Sampling. 2. From each shipment or portion thereof representing a product of the same kind, class and weight, a number of rolls shall be selected at random, equivalent to one-half the cube root of the total number of rolls in the lot, except that in lots of 1000 or less, 5 rolls shall be taken. If the cube root, as calculated, proves to be a fractional number, it shall be expressed as the next higher whole number. For convenience, the following table is given, showing the number of samples to be selected for shipments of various sizes:

Packages in Shipment	Number of Packages Selected	Packages in Shipment	Number of Packages Selected
Up to 1000	5	5 833 to 8 000	10
1001 to 1728	6	8 001 to 10 648	11
1729 to 2744	7	10 649 to 13 842	12
2745 to 4096	8	13 843 to 17 576	13
4097 to 5832	9	17 577 to 21 952	14

EXAMINATION OF FINISHED FABRIC

Width. 3. The width of each roll taken shall be measured to the nearest $\frac{1}{32}$ in. The minimum and maximum width so obtained shall be reported.

Gross Weight per Roll. 4. Each roll taken shall be weighed intact to the nearest $\frac{1}{4}$ lb. and the minimum and maximum gross weight shall be reported.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These methods are in effect a revision of, and replace the former Standard Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing (A.S.T.M. Designation: D 146 – 37) which methods were accordingly discontinued in 1938.

Wrapping and Packing Materials. 5. Each roll sampled shall be stripped. All the wrappers and packing material shall be weighed together to the nearest $\frac{1}{4}$ lb. and the average maximum weight thereof per roll shall be reported.

Area per Roll. 6. Each roll shall be unwound, observing the workmanship and finish while so doing. The length and width of each roll shall thereupon be measured to the nearest $\frac{1}{4}$ in. and the square feet of material contained in each roll calculated.

Net Weight per Roll. 7. The rolls shall be rewound, fastened with pieces of light string and then each roll shall be weighed to the nearest $\frac{1}{4}$ lb. In the case of felted fabrics, calculate the weight of each roll in pounds per 100 sq. ft. and report the maximum and minimum, likewise recording the average for the rolls sampled, which shall be regarded as the corresponding weights of the entire shipment. In the case of woven fabrics, calculate the weight of each roll in ounces per square yard, and report the minimum, likewise recording the average for the rolls sampled, which shall be regarded as the corresponding weights of the entire shipment.

Weight per Unit Area. 8. From the rolls examined, select the one whose weight per unit area is nearest the average weight per unit area of the lot. The roll so selected shall be laid flat, the first convolution or two carefully unwound, and with a knife and straight edge the sheet shall be cleanly cut across at right angles to the edges. A section measuring 30 in. in the direction of the roll's length shall be removed. If the material is surfaced with sand or other fine material any detached particles belonging to each 30-in. section shall be retained. The width of each section shall be measured to the nearest $\frac{1}{32}$ in. Each section, together with any detached surfacing, shall be weighed to the nearest gram. The weight in pounds per 100 sq. ft. or the weight in ounces per sq. yd. shall be calculated from the formulas:

$$\text{Pounds per 100 sq. ft.} = 1.0582 \times \frac{\text{Weight of 30-in. section in grams}}{\text{Width of 30-in. section in inches}}$$

$$\text{Ounces per sq. yd.} = 1.5238 \times \frac{\text{Weight of 30-in. section in grams}}{\text{Width of 30-in. section in inches}}$$

This must check within 1 per cent of the average weight per unit area of shipment (Section 7). If the sample fails to do this, then additional samples shall be cut from the same roll, until one is obtained which does, which sample shall be kept for further examination.

NOTE.—As a referee method or in case any dispute arises regarding the properties as may be ascertained from the particular sample selected, a 30-in. sample shall be taken and examined separately from each roll sampled in Section 2.

Detached Comminuted Surfacing. 9. If the material is surfaced with sand or other finely comminuted material, the surfacing shall be swept with a moderately stiff brush from all the 30-in. sections taken. All the material thus removed shall be caught and weighed to the nearest ounce. From the aggregate areas of all the sections taken, the average weight of detached comminuted surfacing shall be calculated in pounds per 100 sq. ft.

Thickness. 10. The thickness of each specimen shall be measured at ten equally spaced points at least 1 in. from a cut edge with a dead-weight micrometer gage having a cylindrical foot and anvil with flat bearing surfaces 1 sq. in. in area. The load used shall be 2 lb. per sq. in. The thickness for each roll sampled shall be averaged and the minimum, maximum and average thicknesses calculated to the nearest 0.001 in.

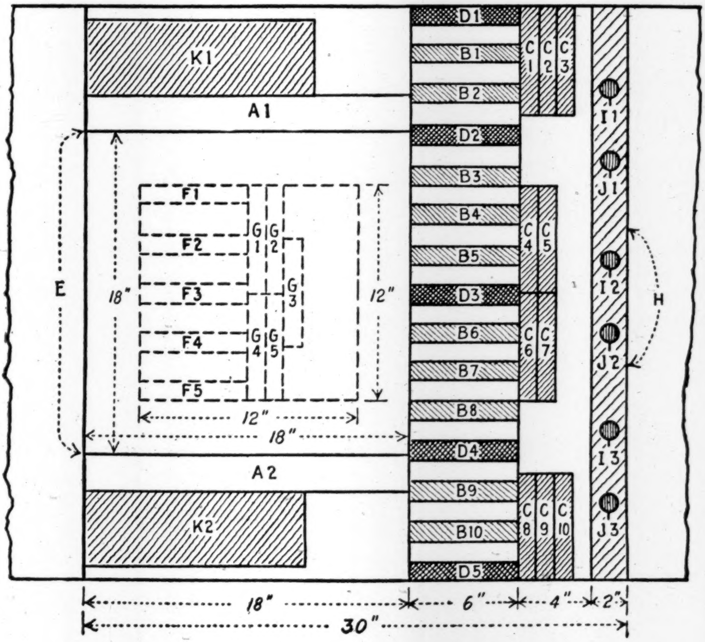

FIG. 1.

Moisture. 11. From each specimen, 2-in. strips shall be cut as shown at *A-1* and *A-2* in Fig. 1. The 2-in. strips shall be cut into 1-in. squares. About 50 g., selected at random, shall be accurately weighed and distilled with 100 cc. of a coal-tar distillate of which 5 to 10 per cent boils below 100° C. (212° F.) and of which at least 90 per cent distills up to 180° C. (356° F.) in an apparatus of the form and under the conditions prescribed in the Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (A.S.T.M. Designation: D 95) of the American Society for Testing Materials.[1] The flask containing the solvent and sample shall be heated in a paraffin bath at a temperature of 302 to 338° F. (150 to 170° C.) until no further water passes over. The distillate shall be allowed to stand in the graduated receiver until the water separates, whereupon the volume of water shall be measured and its weight calculated. From this, the average percentage of moisture in the fabric, as received, shall be calculated.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 997.

Strength. 12. (*a*) *Felted Fabrics.*—With a photographic trimmer having a stop attached exactly 1 in. behind the blade, ten strips shall be cut with the fiber grain, as shown at *B-1* to *B-10* (Fig. 1) and ten strips across the fiber grain as shown at *C-1* to *C-10.* Each strip should measure 6 in. and have parallel sides 1 in. apart (within $\frac{1}{32}$ in.) with the edges cut straight and clean. Both sets of strips shall be tested at 70° F. (21.1° C.), using a tension testing machine such as the Scott Strength Tester (Type F, 100 lb. capacity), the Perkins Strip Tester, or equal, in which the clamps are attached to swivels free to move in any direction. The test strips shall be gripped 1½ in. on each end, leaving approximately 3 in. between the clamps. The tension shall be increased by causing the lower clamp of the machine to travel at a uniform speed of 12 in. per minute. If any strip breaks nearer than ½ in. to either clamp, the reading shall be disregarded, and an additional strip shall be tested in its place. The ten readings, with and across the grain, respectively, shall be averaged for each roll sampled. From these results the average strength with and across the fiber grain, respectively, of the fabric as supplied, shall be calculated.

(*b*) *Woven Fabrics.*—Woven fabrics shall be tested at 70° F. (21.1° C.) in accordance with the *Grab Method* as described in Section 10 of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

NOTE.—As a referee method, or in case any dispute arises regarding the strength, the test shall be repeated, with the exception that the fabric before testing shall be exposed at least two hours in an atmosphere of 65 per cent relative humidity at 70° F. (21.1° C.).

Pliability. 13. (*a*) *Felted Fabrics.*—From the sample selected in accordance with Section 8, ten strips 1 in. in width by 8 in. in length shall be cut, five in the direction of and five across the fiber grain. They shall be immersed in water at 77 F. (25 C.) for 10 to 15 min., then removed and each strip immediately bent 90 deg. over the rounded edge of a block, at a uniform speed in approximately two seconds time. The block shall be 3-in. square by 2 in. in thickness with rounded corners of $\frac{1}{2}$-in. radius for 15-lb. felts and $\frac{3}{4}$-in. radius for 30-lb. felts. In bending, the strips shall be held by hand tightly against the upper 2 in. face of the block, and the projecting end of the strip shall be bent over the rounded corner without exerting any strain other than that required to keep the strip in contact with the block and to avoid kinking. Any surface ruptures exceeding $\frac{1}{8}$-in. in length shall be considered failures.

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 220.

(*b*) *Woven Fabrics.*—From the samples selected in accordance with Section 8, five strips 1 in. in width by 6 in. in length shall be cut in the direction of the warp. They shall be immersed in a cooling mixture of ice and water at 0 C. (32 F.) for 10 to 15 min., then removed and each strip immediately bent over a $\frac{1}{16}$-in. mandrel through an arc of 190 deg. at a uniform speed in approximately two seconds and then through 360 deg. over the same mandrel in the opposite direction. The strips shall then be dried thoroughly and examined. If one or more of the test strips crack, ten strips from another portion of the sample shall be cut and the test repeated. If one or more of these strips crack, the material shall be considered as failing to meet the specifications.

Water Absorbed.

14. (*a*) A section 18 in. square (as shown at *E*, Fig. 1) shall be cut from each specimen, weighed, and completely immersed in distilled water at 77° F. (25° C.) for 24 hours. The specimen shall then be removed and dried superficially by pressing lightly between two towels. As the moisture enters through the edges of the sheet more rapidly than through the surfaces, each specimen shall be trimmed to exactly 12 in. square, representing four-ninths of the original area, and reweighed rapidly. The increase in weight shall be calculated on the basis of the original test specimen by multiplying by $2\frac{1}{4}$. The percentage increase in weight represents the water absorption. The minimum, maximum and average for the shipment shall be calculated.

(*b*) Five strips shall be cut with the fiber grain as shown at *F 1* to *F 5* (Fig. 1); five other strips shall be cut across the fiber grain as shown at *G 1* to *G 5* (Fig. 1) and the strength shall be redetermined as in Section 12. The decrease in strength in percentage shall be calculated after the specimen has been subjected to water.

Loss on Heating.

15. (*a*) *Asphalt Saturated Products Only.*—From each specimen, 12 by 6-in. strips shall be cut at *K-1* and *K-2* in Fig. 1, care being taken not to disturb any of the detached surfacing. Each strip shall be weighed and suspended in the center of an air oven maintained at 221° F. (105° C.) ±5° F. (3° C.) with a thin wire fastened through holes punctured near one edge. The thermometer shall be inserted in the oven to such a depth that its bulb will be in line with the center

of the specimens. The strips shall be kept in the oven for exactly 5 hours, then cooled and removed carefully, and each specimen weighed. The average loss shall be calculated as a percentage and the average percentage of moisture (ascertained in Section 11) deducted. The final figure shall represent the average loss on heating, exclusive of moisture.

Extraction of Saturant.

(*b*) *Coal-Tar Saturated Felt Only.*—From the rolls making up the sample, strips 6 in. wide shall be cut across the sheet. Sufficient of these shall be taken to make up a sample of 250 g. ± 5.0 g. These strips then shall be rolled up and placed in the wire basket of the extraction apparatus described in the Standard Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (A.S.T.M. Designation: D 147) of the American Society for Testing Materials[1] or other extraction apparatus of suitable construction. The sample shall then be covered with a disk of soft filter paper to insure an even distribution of the solvent. The extraction shall be carried out as described in Methods D 147.

Recovery of Saturant from CS_2 Extract.

The CS_2 extract containing the bitumen shall be transferred to a 500-cc., short-neck, round-bottom flask. The flask shall be equipped with a Hempel column, 16 cm. in length, 15 mm. in inside diameter and filled to a depth of 5 cm. with glass beads. The Hempel column shall be connected with a water cooled condenser. A -2 to $+80°$ C. thermometer as described in the Standard Method of Float Test for Bituminous Materials (A.S.T.M. Designation: D 139) of the American Society for Testing Materials[2] shall be placed in the Hempel column so that the top of the bulb shall be opposite the bottom of the tubulure. Distillation for the removal of CS_2 shall be continued by means of a steam bath until drops cease to fall from the condenser. The distillation then shall be carried out over a small flame, heating carefully and observing the thermometer until the distillation ceases and the temperature of the vapor as indicated by the thermometer shows no further rise on slightly increasing the flame.

Distillation of Saturant.

When the contents of the flask is sufficiently cool to be poured without appreciable vaporizing, 100 g. ± 0.1 g. shall be distilled in accordance with the Standard Method of Test for Distillation of Creosote (A.S.T.M. Designation: D 246) of the American Society for Testing Materials.[3]

Fractions shall be taken at 210° C. and 235° C. and the distillation stopped at that point. The per cent of distillate by weight at each temperature shall be calculated on the basis of the weight of sample taken for distillation.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1143.

[2] *Ibid.*, p. 1061.

[3] *Ibid.*, p. 542.

DESATURATING THE FABRIC

Desaturated Fabric.

16. From each roll sampled, a 2-in. strip (within $\frac{1}{32}$ in.) shall be cut across the specimen as shown at *H* (Fig. 1). Each strip shall be extracted with carbon disulfide[1] in an extractor described in Section 4 of the Standard Methods of Testing Bituminous Mastics, Grouts and Like Mixtures (A.S.T.M. Designation: D 147) of the American Society for Testing Materials,[2] the extraction being continued for several hours after the drippings have become colorless. The desaturated fabric shall be removed and heated in a ventilated oven at 225° F. (107.1° C.), cooled in a desiccator, any adhering comminuted surfacing being brushed off and retained, and weighed as rapidly as possible. The heating shall be repeated until the weight of the fabric remains constant as determined by two consecutive weighings taken not less than ten minutes apart which shall show a further loss of not more than 0.1 per cent. This will give the weight of the fabric in the moisture-free state. Where a coal-tar pitch saturant has been used, the moisture-free weight of the desaturated fabric shall be corrected for the carbonaceous matter retained mechanically in its interstices, by means of the method described in Section 17.

Retained Carbonaceous Matter.

17. The following colorimetric method shall be used to ascertain the carbonaceous matter derived from a coal-tar pitch saturant and retained by the desaturated fabric:

(*a*) About 15 g. of an unsaturated fabric of the same general character as the one under examination, shall be macerated by boiling in water, disintegrating with a rotary egg-beater and picking the fibers apart with needles. The fibers shall be filtered through fine cloth and dried at a temperature of 225° F. (107.1° C.) to constant weight. One gram of the fibers shall be accurately weighed into a flask and diluted to exactly 100 cc. with distilled water at room temperature. About 50 g. of glass beads shall be added and the contents of the flask shaken vigorously until the fibers are reduced to a homogeneous pulp in uniform suspension.

(*b*) A distilled coal-tar, having approximately 10 to 25 per cent of insoluble carbonaceous matter, shall be procured and the carbonaceous matter extracted with benzol until it is free from soluble matter; then dried at a temperature of 225° F. (107.1° C.) to constant weight. One gram of the purified carbonaceous matter shall be accurately weighed and diluted to exactly 100 cc. at room temperature with a starch solution of a consistency sufficient to carry the carbonaceous matter into temporary suspension. (A 12.5 per cent solution is recommended.)

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[1] In this test, chloroform may be used as an equivalent solvent.

[2] 1936 Book of A.S.T.M. Standards, Part II, p. 1143.

(*c*) The liquid carrying the fibers, obtained as described in Paragraph (*a*), shall be titrated with the suspension of carbonaceous matter, obtained as described in Paragraph (*b*), and from time to time a field prepared from a drop of the well agitated mixture shall be examined under a microscope at 100 diameters magnification until the color exactly matches a field prepared from the desaturated fabric under examination (obtained as described in Section 16), when both are viewed side by side under parallel conditions. The end-point is fairly sharply defined. The burette reading gives directly the percentage of carbonaceous matter adhering to the moisture-free fabric under examination.

(*d*) The weight of moisture-free fabric ascertained in Section 16 shall be corrected by deducting the weight of adhering carbonaceous matter.

Total Comminuted Surfacing.

18. The total comminuted surfacing plus any filler present in the bituminous saturant represents the sum of the detached comminuted surfacing (Section 9), the amount brushed off from the surface of the desaturated fabric (Section 16), plus the amount recovered upon evaporating and igniting the bituminous extract obtained in accordance with Section 16.

Bituminous Saturant.

19. The weight of bituminous saturant represents the difference between the weight of the original fabric (Section 7), and the sum of the weights of the moisture-free desaturated fabric (Sections 16 and 17), plus moisture (Section 11), plus the total comminuted surfacing and filler present (Section 18).

EXAMINATION OF THE EXTRACTED FABRIC

(*A*) *Woven Fabrics*

Weight.

20. Woven fabrics shall be tested for weight and number of threads per inch in accordance with Sections 6 and 7 of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

(*B*) *Felted Fabrics*

Weight.

21. The weight in pounds per 480 sq. ft. of the desaturated felt (corrected for any carbonaceous matter present) for each specimen examined shall be calculated separately from the formulas:

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 220.

$$\text{“Number”} = \frac{\text{Weight of specimen in grams}}{\text{Area of specimen in square centimeters}} \times 983$$

or

$$\text{“Number”} = \frac{\text{Weight of specimen in grams}}{\text{Area of specimen in square inches}} \times 152$$

This represents the "number" of the moisture-free felt on the felt makers' scale. The minimum, maximum and average "number" of the felt in its moisture-free state shall be calculated. This may be corrected to the condition in which it actually existed in the material under examination, by adding thereto the percentage of moisture as determined in Section 11.

22. A representative sample shall be secured by cutting from each strip of desaturated felt a piece about $\frac{1}{2}$ in. in diameter as shown at *I-1*, *I-2*, and *I-3* (Fig. 1). About 25 g. selected at random from all the specimens sampled in this manner shall be accurately weighed, and incinerated in a weighed porcelain or quartz crucible either over an open flame or in a muffle, until all the carbon is consumed. A few drops of ammonium carbonate solution shall be added, the sample ignited gently, and weighed. The percentage of ash shall be calculated on the basis of the moisture-free felt. **Ash.**

NOTE.—As a referee method, or in case greater accuracy is desired, the three portions taken from each specimen roll shall be weighed and ignited separately. The minimum, maximum and average of ash present shall be calculated on the basis of the moisture-free felt.

TENTATIVE METHOD OF TESTING FILMS DEPOSITED FROM BITUMINOUS EMULSIONS[1]

A.S.T.M. Designation: D 466 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.[2]

RESISTANCE TO FLOW UNDER HEAT (SLIDE TEST)

Scope

1. The slide test is applicable to bituminous emulsions or reinforced emulsions intended to be applied at the rate of not less than 3 gal. per 100 sq. ft. and on substantially vertical surfaces.

Apparatus

2. The following apparatus will be required:

(*a*) *Brass Mask*.—A brass mask approximately $\frac{7}{64}$ in. in thickness with a rectangular opening of at least 12 sq. in.

(*b*) *Tiles*.—Unglazed ceramic tiles[3] approximately 6 by 6 in. or of sufficient size to accommodate the opening of the mask.

Procedure

3. (*a*) *Preparation of Tile*.—The tile shall be immersed in distilled water for at least 10 min. and the excess water removed immediately before application of the emulsion.

(*b*) *Preparation of Film*.—The sample of emulsion shall be thoroughly stirred. The brass mask shall then be applied to the smooth face of the tile and the emulsion spread over the area of the tile within the mask opening. The excess emulsion shall be doctored off with a flat scraper so that the film after drying shall be not less than 0.04 in. (1 mm.) in thickness.

(*c*) *Drying*.—The coated tile shall then be dried to constant weight in an atmosphere of low relative humidity at room temperature and weighed every 24 hr. A film shall be considered dry when the loss in two successive 24-hr. weighings is not greater than 0.1 g.

NOTE.—Drying may be hastened by placing the specimen in a current of air from an electric fan.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

[2] Revision accepted by Committee E-10 on Standards, August 25, 1938.

[3] Suitable unglazed tile can be obtained from the Robertson Art Tile Co., Morrisville, Pa.

(*d*) *Testing.*—After drying and removing the brass mask, the coated tile shall be suspended vertically in the center of an air oven maintained at 176 F. ±5 F. (80 C. ±3 C.). The internal dimensions of the oven shall not be less than 12 by 12 by 12 in. An electrically heated oven is recommended. A thermometer shall be inserted in the oven to such depth that its bulb will be in line with the center of the specimen. The tile shall be maintained at the prescribed temperature for exactly 2 hr. Any sliding shall be determined by a reference line placed originally on the tile, coincident with the lower edge of the dried film.

RESISTANCE TO WATER ACTION

Scope

4. The purpose of this test is to determine the ability of the dried film to retain its adhesion and to resist re-emulsification after immersion in water.

Procedure

5. (*a*) *Preparation of Film.*—The film to be tested shall be prepared as described in Sections 2 and 3.

(*b*) *Testing.*—After drying, a ring approximately 2 in. in diameter and 1 in. in height shall be pressed into the surface of the coated tile. The ring shall be filled with tap water and the test specimen maintained at room temperature between 70 to 90 F. (21 to 32 C.). After 24 hr. the character of the bituminous film shall be noted by cutting with a knife or teasing needle. Adhesion or bond shall be determined by making intersecting cuts with the knife or needle and lifting the cut film at the point of intersection. Re-emulsification is indicated if the water becomes darkened by rubbing the wet surface of the film lightly with a rubber policeman.

TENTATIVE METHOD OF TEST
FOR
ACETONE EXTRACTION OF PHENOLIC MOLDED OR LAMINATED PRODUCTS[1]

A.S.T.M. Designation: D 494 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method describes the procedure for determining the amount of acetone-soluble matter in molded or laminated phenolic products.

Apparatus

2. (*a*) *Sieves.*—The set of sieves used shall consist of sieves Nos. 40 and 140, with a cover and receiving pan, conforming to the requirements of the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2]

(*b*) *Extraction Apparatus.*—The apparatus may be of the type shown in Fig. 1, or a Wiley-Richardson type, as shown in Fig. 2. The former type is more suitable for use with small electric hot plates while the latter is more suitable for use with oil or water baths. In either case, it shall be possible to control the temperature so that the rate of extraction can be regulated accurately.

(*c*) *Drying Dishes.*—The drying dishes shall be thin tinfoil dishes $2\frac{1}{2}$ in. in diameter, $1\frac{1}{16}$ in. in height, and from 0.004 to 0.005 in. in wall thickness, of the type used for milk analysis and for bottle caps.

Preparation of Sample

3. (*a*) *Precautions.*—It is of utmost importance that extreme care shall be taken during the preparation of the sample for extraction. Drillings taken from a large molded product shall be truly representative of all sections of the part in proper proportions. The drills for sampling shall be kept sharp and so operated that no undue heating of the material shall occur which will tend to pre-cure the material.

(*b*) If it is impracticable to obtain samples by drilling, the parts may be broken up with a lathe, planer, milling machine or a suitable grinder. A mortar and pestle, or a pebble mill is considered suitable as a grinder, provided no perceptible heating occurs during the grinding procedure. A sharp file or rasp may be used for procuring the sample where the size or shape of the part is such that no other method is suitable.

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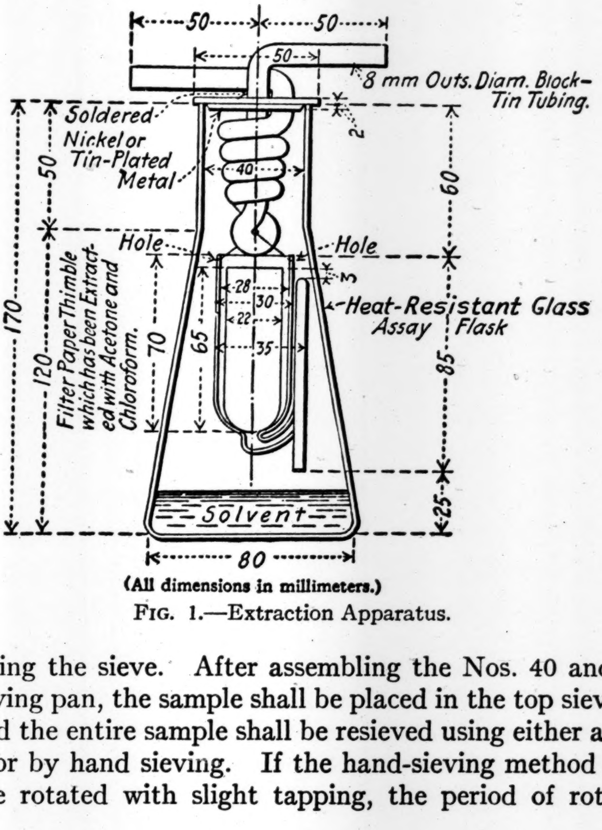
[1] Under the standardization procedure of the Society, this method is under the juristiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] See p. 1289.

(*c*) In any case, the particles of the sample shall be of the smallest size practicable, so that they will pass through the No. 40 sieve with the minimum of reworking or grinding. It is important in preparing the sample that the smallest possible volume shall be obtained for a unit weight of the material.

(*d*) The sample shall be sieved through a No. 40 sieve and that part which will not pass through shall be reground and blended with the original material passing the sieve. After assembling the Nos. 40 and 140 sieves and the receiving pan, the sample shall be placed in the top sieve, the cover placed on, and the entire sample shall be resieved using either a mechanical sieve shaker or by hand sieving. If the hand-sieving method is used, the sieve shall be rotated with slight tapping, the period of rotation being 5 min.


50
50
50
8 mm Outs. Diam. Block-Tin Tubing.
Soldered
Nickel or Tin-Plated Metal
40
2
50
60
Hole
Hole
3
28
30
22
35
Heat-Resistant Glass Assay Flask
170
120
Filter Paper Thimble which has been Extracted with Acetone and Chloroform.
70
65
85
25
Solvent
80

(All dimensions in millimeters.)

FIG. 1.—Extraction Apparatus.

(*e*) After sieving, the sample shall be placed immediately in an air-tight container to prevent absorption of moisture by the powder and the consequent error in results.

Procedure

4. (*a*) *Extraction.*—The extraction procedure shall be carried out in triplicate. A 3.000-g. portion of the powdered sample shall be accurately

weighed into a tared, open-texture quantitative filter paper,[1] 12.5 to 15 cm. in diameter, or a standard, single-thickness extraction thimble, 80 by 22 mm., trimmed if necessary. After folding over the thimble or filter paper containing the sample so that none of the powder can float out, it shall be placed in a desiccator until ready to insert in the syphon.

(*b*) The filter paper or thimble containing the weighed sample shall be pressed into the syphon in such a way that the outlet of the bottom is not plugged. The condenser and the syphon shall be placed in the extraction tube and 50 ml. of c.p. acetone added. The water shall be started through the condenser and the heat adjusted so that the syphon fills and empties between 15 and 20 times per hour. This rate shall be carefully maintained and the sample shall be extracted for 4 hr. After the syphon empties, the flask shall be removed and the contents poured into an individually weighed tinfoil dish. The flask shall be washed three times with the smallest possible quantity of acetone, using a wash bottle, and the washings shall be added to the extracted liquid in the tinfoil dish.

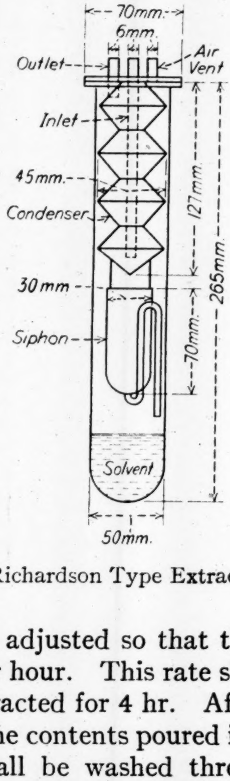


FIG. 2.—Wiley-Richardson Type Extraction Apparatus.

NOTE.—If an oil or water bath is used for heating, the height of the liquid in the bath should not come above 1 in. below the highest level of the acetone in the syphon before the syphon starts to discharge.

(*c*) *Drying.*—The tinfoil dish shall be placed in a well-ventilated drying chamber, maintaining a temperature of 50 ± 2 C. and the sample shall be dried to constant weight. Between dryings, all dishes containing the residue shall be kept in a desiccator to prevent the absorption of moisture.

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[1] W. and R. Balston, Ltd., Genuine Whatman Filter Paper, No. 41H is suitable for this purpose.

NOTE.—It is very important that the specified temperature shall be maintained, otherwise consistent results can not be obtained between different laboratories. An electrically-heated oven should not be used unless it is exceedingly well ventilated as the acetone fumes are liable to come in contact with the heated coils and cause an explosion.

Calculations

5. The percentage of acetone extractable matter in the specimen shall be calculated as follows:

$$\text{Acetone extractable matter, per cent} = \frac{W - D}{S} \times 100$$

where W = the weight of the dish and extract,
D = the weight of the dish, and
S = the weight of the original sample.

Report

6. The report shall include the following:

(*a*) The percentage of acetone extractable matter for each sample, and

(*b*) The average percentage of acetone extractable matter for the three samples.

TENTATIVE METHOD OF TEST
FOR
ARC RESISTANCE OF SOLID ELECTRICAL INSULATING MATERIALS[1]

A.S.T.M. Designation: D 495 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method of test is intended for determining the relative arc resistance of all solid electrical insulating materials.

Nature of Test

2. A high-voltage low-current a-c. arc, drawn between two tungsten pointed electrodes resting upon the surface of the material under test, is increased at 1-min. intervals until the material fails by becoming conducting. The time required to reach failure is a measure of the arc resistance of the material.

Apparatus

3. (*a*) A transformer of any convenient rating equal to or greater than 12 kv. and 1.2 kva. may be used. The source of supply of alternating-current energy shall be not less than 1 kva., and the frequency shall be 60 cycles per sec. (Note 1).

NOTE 1.—Where it is desired to test only organic insulating materials, a transformer rating of 12 kv. and 0.5 kva., or less, depending upon the material, will be satisfactory and the higher current steps will not be required.

(*b*) The secondary current of the transformer shall be measured by a suitable milliammeter (Note 2) and shall be controlled in magnitude by a variable resistance or inductance in the primary circuit.

NOTE 2.—Depending upon the transformer design, more or less high-frequency current is present in the high-voltage circuit, and unless proper precautions are taken, erroneous milliammeter readings may be obtained.

(*c*) A motor-driven interrupter shall be used to give the required cycles for the three lower steps of the test.

(*d*) A wiring diagram of the equipment required for the test is shown in Fig. 1.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-9 on **Electrical Insulating Materials.**

Electrodes

4. The electrodes shall consist of threaded steel rods 0.186 in. in diameter, equipped with tungsten wire tips 0.060 in. in diameter, which shall have a conical point with a 60-deg. included angle. The electrodes shall be screwed into brass inserts in a wooden block at 45 deg. to the vertical and shall be adjusted to give a gap of 0.320 in. (0.813 cm.). Both electrodes shall lie in the same vertical plane. The weight of the block shall be supported on the two electrode points and on a third adjustable screw at the back of the block. The method of mounting the electrodes is illustrated in Fig. 2.

Test Specimens

5. The test specimens may be of any size or shape, provided a flat, or nearly flat, surface of about 0.16 sq. in. (1 sq. cm.) in area is available for each test.

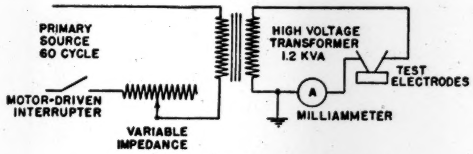

FIG. 1.—Wiring Diagram.

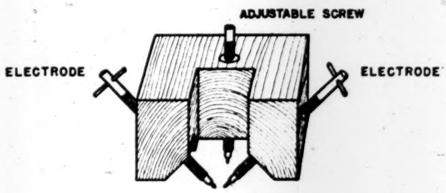

FIG. 2.—Electrode Mounting.

Procedure

6. (*a*) The arc-resistance test shall be made in air, sheltered from drafts, and with the specimen at room temperature. The electrode points shall be kept sharp and shall rest on the specimen in a horizontal position, as shown in Fig. 2. The open circuit voltage of the testing transformer shall be adjusted to 12 to 15 kv. before starting the test.

(*b*) The sequence of steps, as shown in Table I, may be manually controlled by the operator or automatically controlled by a timing and switching circuit. The time in seconds from the start of the test until the failure of the material shall be recorded. Failure occurs when the surface of the material under test becomes conducting, at which time the arc in air disappears and a bright line appears between the electrodes (Note 3).

NOTE 3.—It is frequently difficult to determine the time of failure of arc-resistant materials, such as refractory materials, porcelain, etc., as the entire surface under test is at white heat for some time before failure. The results of these tests are therefore liable to be considerably influenced by the judgment of the operator. For materials which last through the 100-ma. step, the test shall be discontinued as such high currents rapidly burn away the electrodes and it is very difficult to determine the time of failure.

Number of Tests

7. Unless otherwise specified, 10 tests shall be made.

TABLE I.—SEQUENCE OF 1-MIN. CURRENT STEPS.

Current, ma.	Time Cycle[a]	Approximate Rate of Heat Generation, watts	Total Time, sec.
10	$\frac{1}{4}$ sec. on, $1\frac{3}{4}$ sec. off	3	60
10	$\frac{1}{4}$ sec. on, $\frac{3}{4}$ sec. off	6	120
10	$\frac{1}{4}$ sec. on, $\frac{1}{4}$ sec. off	12	180
10	Continuous	24	240
20	Continuous	34	300
30	Continuous	45	360
40	Continuous	56	420
50	Continuous	67	480
60	Continuous	79	540
70	Continuous	91	600
80	Continuous	103	660
90	Continuous	115	720
100	Continuous	128	780

[a] In the earlier steps an interrupted arc is used to obtain a less severe condition than the continuous arc; a current of less than 10 ma. produces an unsteady arc.

Report

8. Unless otherwise specified, the report shall include the following:

(*a*) The time in seconds for each failure and the average time of failure for the 10 tests.

(*b*) The current step at which each failure takes place.

TENTATIVE METHODS OF TEST

FOR

DIELECTRIC STRENGTH OF INSULATING MATERIALS, AT COMMERCIAL POWER FREQUENCIES[1]

A.S.T.M. Designation: D 149 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1922; Revised, 1923, 1924, 1926, 1927, 1930, 1931, 1932, 1933, 1934, 1936, 1938

Scope

1. These methods provide for the determination of dielectric strength of solid, semi-solid, and liquid insulating materials, except where a specific material requires a certain amount of special treatment. In such cases, reference should also be made to the methods for the material to be tested (Note).

Note.—The following methods of the American Society for Testing Materials now provide for dielectric strength tests:

Standard Methods of Testing Molded Materials Used for Electrical Insulation (A.S.T.M. Designation: D 48),[2]
Standard Methods of Testing Electrical Porcelain (A.S.T.M. Designation: D 116),[3]
Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117),[3]
Tentative Methods of Testing Varnishes Used for Electrical Insulation (A.S.T.M. Designation: D 115 - 38 T),[4]
Tentative Methods of Testing Solid Filling and Treating Compounds Used for Electrical Insulation (A.S.T.M. Designation: D 176 - 37 T),[5]
Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (A.S.T.M. Designation: D 229 - 38 T),[6]
Tentative Methods of Testing Varnished Cloths and Varnished Cloth Tapes Used in Electrical Insulation (D 295 - 38 T),[7]
Tentative Methods of Testing Laminated Tubes Used in Electrical Insulation (A.S.T.M. Designation: D 348 - 38 T),[8]
Tentative Methods of Testing Flexible Varnished Tubing Used for Electrical Insulation (A.S.T.M. Designation: D 350 - 38 T),[9] and
Standard Methods of Testing Pasted Mica Used in Electrical Insulation (A.S.T.M. Designation: D 352).[10]

Nature and Types of Tests

2. (*a*) The dielectric strength of an insulating material is the maximum potential gradient that the material can withstand without rupture. It

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] 1937 Supplement to Book of A.S.T.M. Standards, p. 232.

[3] 1936 Book of A.S.T.M. Standards, Part II, pp. 1178, 1167.

[4] See p. 1080.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part. I, p. 988 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1120.

[6] See p. 1046.

[7] See p. 1061.

[8] See p. 1009.

[9] See p. 1074.

[10] 1936 Book of A.S.T.M. Standards, Part II, p. 1216.

is calculated from the breakdown voltage and the thickness of the specimen at or near the point of rupture, and is commonly expressed in volts per mil or volts per millimeter. The value obtained in a test will depend upon the method and conditions of test.

(*b*) In general, the dielectric strength of insulating materials decreases with time of exposure to the electrical stress. Tests involving short exposures are, therefore, primarily comparative and not indicative of the breakdown of the materials under prolonged exposure to lower stresses.

(*c*) For quick determinations of dielectric strength, the short-time test has been devised. For fairly rapid determinations, but laying more emphasis upon the time factor, the step-by-step test has been arranged. For tests involving longer time factors, reference should be made to the methods for the material to be tested (see Note, Section 1).

APPARATUS

Electrical Apparatus

3. (*a*) *Transformer.*—The desired test voltage may be most readily obtained by a step-up transformer energized from a variable low-voltage source. The transformer and its controlling equipment shall be of such size and design that, with the test specimen in circuit, the crest factor (ratio of maximum to mean effective) of the test voltage shall not differ by more than plus or minus 5 per cent from that of a sinusoidal wave over the upper half of the range of test voltage. The crest factor may be checked by means of a sphere gap or peak-reading voltmeter in conjunction with an r.m.s. voltmeter. For test specimens of small capacitance, a well-designed potential transformer may be adequate. For specimens of high capacitance, a transformer of several kilovolt-amperes rating may be necessary. Where the wave-form can not be determined conveniently, a transformer having a rating of not less than 2 kva. shall be used for voltages not exceeding 50,000 v., and one having a rating of not less than 5 kva. for voltages exceeding 50,000 v. Tests shall be made at commercial power frequencies.

(*b*) *Circuit Breaker.*—The test transformer circuit shall be protected by an automatic circuit-breaking device designed to open instantaneously on the current produced by breakdown of the test specimen. Excessive flow of current at the time of breakdown causes pitting and heating of the electrodes, and thereby increases the work of electrode maintenance and time of testing.

(*c*) *Voltage Control.*—The rate of voltage rise shall not, for short-time tests, vary more than plus or minus 25 per cent from the specified rate. Control of voltage may be secured in one of several ways: (*1*) generator-field regulation, (*2*) induction regulator, (*3*) variable-ratio auto-transformer, or (*4*) resistance-potential divider. In general, variable-ratio auto-transformers or resistance-potential dividers have better voltage-time characteristics than induction regulators and furnish the most satisfactory means of regulation on constant potential sources of supply, where the volt-ampere demand is low. Motor drive, with variable speed control, should be preferred to manual drive because of the difficulty of maintaining reasonably uniform rate of voltage rise with the latter.

NOTE.—A small variable auto-transformer, motor controlled, with automatic limit features, is described in the Appendix.

(*d*) *Voltmeter.*—The voltage shall be measured by an approved method which gives root-mean-square values, preferably by means of: (*1*) a voltmeter connected to the secondary of a separate potential transformer, (*2*) an electro-static voltmeter in the high tension circuit, or (*3*) a voltmeter connected to a well-designed tertiary coil in the test transformer. A voltmeter connected to the low-voltage side of the testing transformer or to a tertiary coil may be used only if the ratio of transformation does not change appreciably with load or if the voltmeter corrects or compensates for variations in load.

(*e*) *Voltage Rate Indicator.*—The rate of voltage rise may be determined by some such device as a "rate-of-rise" indicator or by measuring the time required to raise the voltage between two prescribed values. When motor-driven regulating equipment is used, the speed-control rheostat may be calibrated in terms of voltage rise for any particular test transformer.

Electrodes

4. The dielectric strength of an insulating material varies with the thickness of the material and the area and geometry of the test electrodes. Tests made with different electrodes are not comparable. Where materials are made up into forms of uniform thickness, such as sheets and plates, tests shall be made upon that thickness of material. In other cases, a thickness of test specimen and diameter and shape of electrode have been selected that are compatible with convenience of testing. The electrodes used shall be as follows:

(*a*) *Thin Solid Materials* (Sheets and Plates):

(*1*) *Wide.*—Metal disks 2 in. in diameter, and 1 in. in length with the edges rounded to a radius of $\frac{1}{4}$ in.

(*2*) *Narrow* (Tapes).—Opposing cylindrical rods $\frac{1}{4}$ in. in diameter with edges rounded to a radius of $\frac{1}{32}$ in. Upper movable electrode shall weigh 0.1 ± 0.005 lb.

NOTE.—For rubber and friction tapes, reference should be made to the Standard Specifications and Tests for Rubber Insulating Tape (A.S.T.M. Designation: D 119), and for Friction Tape for General Use for Electrical Purposes (A.S.T.M. Designation: D 69) of the American Society for Testing Materials.[1]

(*b*) *Thick Solid Materials.*—Metal disks 1 in. in diameter, and 1 in. in length with edges rounded to a radius of $\frac{1}{8}$ in.

(*c*) *Liquids.*—Metal disks 1 in. in diameter with square edges, mounted with axes horizontal.

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[1] 1938 Supplement to Book of A.S.T.M. Standards, pp. 189 and 194.

(*d*) *Compounds.*—Hemispherical metal electrodes ½ in. in diameter.

(*e*) *Materials Requiring Special Treatment* (Tubes, Varnishes, etc.).—Reference shall be made to the specific methods for the materials to be tested (see Note, Section 1).

TEST SPECIMENS

Test Specimens

5. (*a*) The dielectric strength of an insulating material varies with the thickness of the test specimen. Tests on specimens of different thickness are therefore not comparable. The specimens shall be representative of the material to be tested. Sufficient material shall be available to permit making five satisfactory tests (Section 11).

(*b*) *Thin Solid Materials* (Sheets and Plates).—The test specimens need be only of sufficient area to prevent flashover under the conditions of test.

(*c*) *Thick Solid Materials.*—The breakdown voltage of thick solid materials is so high that special test specimens, of reduced thickness, shall be cut or molded. For details of these specimens, reference shall be made to the specific methods for the materials to be tested (see Note, Section 1).

(*d*) *Liquids.*—For testing liquids, it is necessary to use a special test cup with electrodes rigidly mounted with their axes in a horizontal plane. The cup shall be of such design that no part of it is less than ½ in. from any part of the test faces of the electrodes, when the latter are in testing position. It shall be made of a material of high dielectric strength, insoluble in and unattacked by any of the test liquids. The top of the cup shall be about 33 mm. (1¼ in.) above the top of the electrodes.

(*e*) *Other Materials.*—For a description of the test specimens of other materials, reference shall be made to the specific methods for the materials to be tested (see Note, Section 1).

Conditioning

6. (*a*) The dielectric strength of most insulating materials varies with temperature and humidity. Usually it is desirable to determine the dielectric behavior of a material over the range of temperature and humidity to which it is likely to be subjected in use. As this varies for different materials, for information concerning the conditioning treatment of a particular material reference shall be made to the specific method of test for that material (see Note, Section 1). Materials may be conditioned in a suitably controlled chamber. The test specimens shall be kept in the chamber long enough to reach a uniform temperature and humidity before voltage is applied. The dielectric strength tests shall be made on the specimen while still in the conditioning chamber. For purpose of tests, a high-voltage conductor may be conveniently carried into the chamber through an insulating bushing.

(*b*) For tests made in air, use may be made of any well-designed oven of sufficient size to hold the test equipment. It should be provided with some means of circulating the air, so that approximately constant temperature is maintained around the test specimen, and with a thermometer or thermocouple for measuring the temperature as near the point of test as practicable.

(*c*) For tests under oil, use may be made of an oil bath, provided with some means for circulating the oil, so that the temperature is substantially uniform around the test specimens, and with a thermometer or thermocouple for measuring the temperature as near the point of test as practicable.

Surrounding Medium for Solid Materials

7. In general, it is preferable to test materials in the medium, whether air or oil, in which they are to be used. Where conditions of use are not well defined, materials should be tested in air up to the point where the breakdown is so high that an excessive amount of material is required to prevent flashover or excessive burning of the surface. For specimens having a high breakdown, such as the thicker and high-grade materials, it is usually necessary to make dielectric strength tests under oil, however, it should be understood that breakdown values obtained under oil are not comparable with those obtained in air. For the medium to be employed on a particular material, reference shall be made to the specific method for the material to be tested (see Note, Section 1).

PROCEDURE

Adjustment and Care of Electrodes

8. (*a*) Electrodes shall be held truly coaxial. Where electrodes have flat test faces, the latter shall be parallel to each other. The test faces shall be kept smooth and polished and free from pitting.

(*b*) In the case of a liquid tester, electrodes and cup shall be cleaned by wiping with dry calendered tissue paper or with a clean dry chamois skin and thoroughly rinsing with dry gasoline until they are entirely free from fibers. The spacing of the electrodes shall be checked with a standard round gage having a diameter of 0.100 in., and the electrodes then locked in position. Care shall be taken not to touch the electrodes with the gage or in any other manner after cleaning the electrodes and cup. The test cup shall be filled with dry gasoline, and voltage applied with uniform increase at the rate of approximately 3 kv. per sec. until breakdown occurs. If the breakdown voltage is not less than 25 kv., the cup shall be considered in suitable condition for receiving the test liquid. If a lower test value is obtained the cup shall be cleaned with gasoline and the test repeated.

Preparation of Test Specimen

9. (*a*) *Solid Materials.*—In the preparation of test specimens from solid

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materials, care shall be taken to have the surfaces adjacent to the electrodes parallel and as plane and smooth as the material permits.

(*b*) *Liquids.*—The dielectric strength of liquid dielectrics may be markedly altered by the migration of impurities through the liquid. In order that representative test specimens may be obtained, the container shall be gently tilted or inverted several times in such a way that any impurities present will be thoroughly mixed with the dielectric. Too rapid agitation is undersirable, as it introduces an excessive amount of air into the mixture. Immediately after mixing, the test cup shall be filled with liquid to a height of not less than 20 mm. (0.787 in.) above the top of the electrodes. In order that entrapped air may escape, the container shall be gently rocked a few times and the liquid allowed to stand in the cup for 3 min. before voltage is applied. Where more than one test is made on the same specimen, the liquid shall be allowed to stand for 1 min. between tests.

(*c*) *Other Materials.*—For the preparation of specimens of insulating compounds, varnish films, etc., reference shall be made to the specific methods for the materials to be tested (see Note, Section 1).

Application of Voltage

10. (*a*) *Short-Time Test.*—The voltage shall be increased from zero to breakdown at a uniform rate. For solid materials, the rate of rise shall be 0.5 or 1.0 kv. per sec., depending on the total test time required and the voltage-time characteristic of the material. For the rate applicable to a given material, reference should be made to the test method for that material. For liquid materials, the rate of rise shall be 3 kv. per sec.

(*b*) *Step-by-Step Test.*—An initial voltage shall be applied equal to 50 per cent of the breakdown voltage in the short-time test, adjusted as shown in the following table:

BREAKDOWN VOLTAGE BY SHORT-TIME METHOD	ADJUST 50 PER CENT OF BREAKDOWN VOLTAGE TO THE NEAREST
25 kv. or less	1.0 kv. (except as otherwise specified)
Over 25 to 50 kv., incl	2.0 kv.
Over 50 to 100 kv., incl	5.0 kv.
Over 100 kv	10.0 kv.

The voltage shall then be increased in equal increments as stated in the various material specifications, the voltage being held at each step for a definite time as stated in the specifications. The change from each step to the next higher shall be made as rapidly as possible, and the time of change included in the succeeding test interval.

Number of Tests

11. Unless otherwise specified, five tests shall be made. If the average deviation from the mean exceeds 10 per cent, or if any individual test deviates more than 15 per cent from the mean, five additional tests shall be made. The dielectric strength shall be determined from the average of all tests.

Thickness of Solid Materials

12. Unless otherwise specified, the number of thickness determinations shall be at least equal to the number of punctures. The measurements shall be made on material undisturbed by breakdown, but as near the point of breakdown as possible. Measurements shall be made in accordance with the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 – 36 T) of the American Society for Testing Materials.[1]

Report

13. Unless otherwise specified, the report shall include the following:

(*a*) The thickness of the specimen as determined in accordance with Section 12,

(*b*) Total volts at each puncture,

(*c*) Volts per mil for each puncture,

(*d*) The average, maximum, and minimum volts per mil for each sample,

(*e*) The temperature of the test specimen,

(*f*) The percentage relative humidity of the surrounding air,

(*g*) The conditioning treatment,

(*h*) The duration of the test,

(*i*) In the step-by-step test, the value of the initially applied voltage and the value of the voltage at each step, and

(*j*) The size and type of electrodes.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1026 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1196.

(See Appendix on page 1008)

APPENDIX

A simple form of motor-operated voltage controller is shown in Fig. 1. The control element is a variable auto-transformer, *A*, of the slide-wire type, the slider of which is driven through a system of reduction gearing, *B*, by a small direct current motor, *C*. The auto-transformer supplies the primary of the testing transformer.

The motor is provided with a reversing switch, so that it may be operated either forward or in reverse. For forward operation, a variable resistor is connected in series with the armature so that the speed may be adjusted to any required value. Where one specific testing transformer is used, the control handle of the resistor may be alibrated in terms of rate of voltage rise. Rapid adjustment of the rate of rise to the value desired is thereby secured without subsequent measurements. In reverse, the resistor is out of circuit, so that the motor operates at maximum speed.

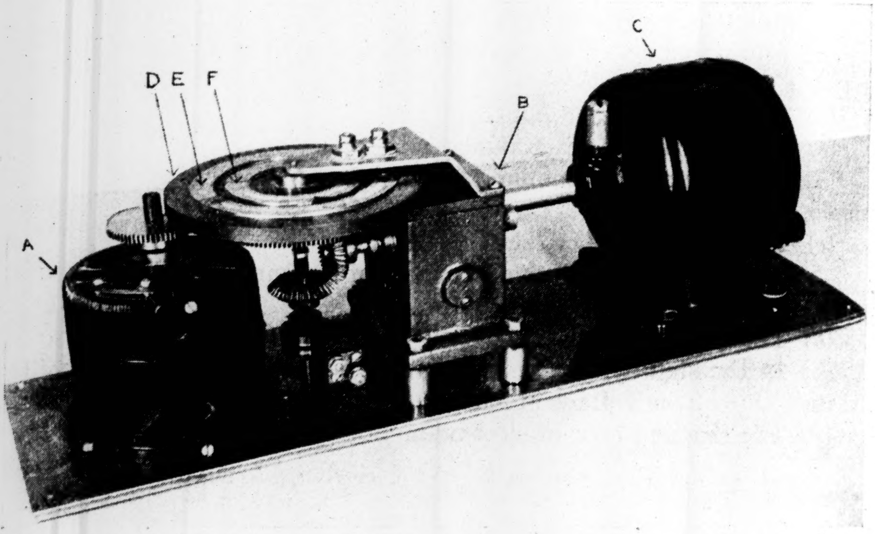

Fig. 1.—Variable Auto-Transformer, Motor Controlled, with Automatic Limit Features.

Over-travel of the motor is prevented by connecting the motor operating circuits through segments, *EF*, on the insulating wheel, *D*, which is attached to one of the gears. One segment is connected in the "forward" circuit, and the length of this is adjusted so that the circuit is automatically opened when the maximum available voltage is reached. The other segment is connected in the reverse circuit, and this is timed so that the circuit automatically opens when the voltage is reduced to zero.

TENTATIVE METHODS OF TESTING LAMINATED TUBES USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 348 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1932, 1934, 1935, 1938.

Scope

1. These methods are intended to apply to laminated tubes to be used as electrical insulation.

TENSILE STRENGTH

Apparatus

2. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned. Steel or brass plugs, $3\frac{1}{2}$ in. in length and of a suitable diameter with edges rounded to $\frac{1}{16}$-in. radius will be required. The plugs shall fit the specimen to within 0.010 in. They can be conveniently located in the tube by separating and supporting them on a metal rod, the lower end of which is screwed into the lower plug, and the upper end rests in a loose socket as shown in Fig. 1.

Specimens

3. Test specimens shall be 12 in. in length. Where the wall thickness of tubing is $\frac{1}{8}$ in. or over, a lathe cut 1 in. in width and $\frac{1}{32}$ in. in depth, with corner rounded to a radius of 3 in. shall be made around the tube at the center.

Procedure

4. Five specimens shall be tested. The average inside and outside diameters determined from at least two measurements 90 deg. apart shall be measured at the groove to the nearest 0.001 in. and the cross-section area shall be calculated from these dimensions. The

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

metal plugs shall be assembled with the tube as shown in Fig. 1. This assembly shall then be grasped in the V-notched jaws of the testing machine.

Speed of Testing Machine

5. The cross-head speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.05 in. per minute when the machine is running idle.

Report

6. The report shall include the following:

(*a*) The average inside diameter of the specimen expressed to the nearest 0.001 in. determined from at least two measurements 90 deg. apart.

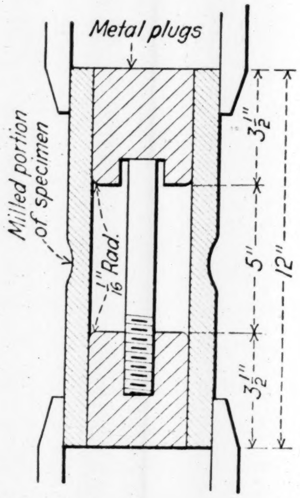

FIG. 1.—Metal Plugs Used for Tension Test, Showing Location of Plugs in Test Specimen.

(*b*) The average outside diameter of the specimen expressed to the nearest 0.001 in. determined from at least two measurements 90 deg. apart.

(*c*) The average outside diameter of the reduced section expressed to the nearest 0.001 in., if a groove was used.

(*d*) The full wall thickness of the specimen.

(*e*) The net area of the test section.

(*f*) The breaking load of each specimen in pounds or kilograms.

(*g*) The tensile strength of each specimen in pounds per square inch or kilograms per square centimeter.

(*h*) The room temperature.

COMPRESSIVE STRENGTH

Apparatus

7. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable at the top. The metal bearing plates shall be directly in contact with the ends of the test specimen.

Specimens

8. Samples shall be tested as-received in specimen lengths of 1 in. Care shall be taken in cutting the specimens for the axial test to have the ends of the specimens cut accurately at right angles to the axis of the tube. Specimens which are not cut squarely are likely to give low results on test.

Procedure

9. Five specimens shall be tested axially, with the load applied perpendicular to the faces or ends of the specimen, and five specimens shall be tested diametrically, with the load applied perpendicular to the tangent at point of application.

Report

10. The report shall include the following:

(*a*) The average inside and outside diameters of the specimen expressed to the nearest 0.001 in., each determined from at least two measurements 90 deg. apart.

(*b*) The average wall thickness of the specimen expressed to the nearest 0.001 in.

(*c*) The direction of application of the load.

(*d*) The load on each specimen at the first sign of rupture, in pounds or kilograms.

(*e*) The ultimate compressive strength in pounds per square inch or kilograms per square centimeter, calculated from the data obtained on the application of the load perpendicular to the face of the specimen.

WATER ABSORPTION

Specimens

11. (*a*) Specimens of tubes having inside diameters less than 3 in. shall be the full section of the tube and 1 in. in length. For larger tubes, a rectangular specimen shall be cut 3 in. in length in the cir-

cumferential direction of the tube and 1 in. in width lengthwise of the tube.

(*b*) The specimens shall be sawed from the sample so as to have smooth edges free from cracks. The cut edges shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations shall be slow enough so that the material is not heated appreciably. The specimens shall be rinsed with gasoline to remove any oil from the machining operation, wiped with a dry cloth and allowed to stand in air for 2 hours to remove the gasoline.

Procedure

12. (*a*) The specimen shall be dried in an oven for 1 hour at 105 to 110 C. and cooled in a desiccator. For materials which will not withstand this temperature the drying shall be omitted.

(*b*) The dried specimen shall be immersed in distilled water maintained at a temperature of 25 C. ± 2 C. (77 F. ± 3.6 F.) throughout the test. At the end of 2 hours, the specimen shall be removed from the water, the surface water wiped off with a dry cloth, weighed immediately, and then replaced in the water. If the specimen is $\frac{1}{16}$ in. in thickness or less it shall be weighed in a weighing bottle. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen.

(*c*) After 24 hours' immersion the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24 hours' immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen. If the individual 24-hour absorptions differ by more than 10 per cent from the average absorption of the two specimens, the test shall be repeated.

Report

13. The report shall include the following:

(*a*) The average inside and outside diameters of the specimen.

(*b*) The average wall thickness of the specimen.

(*c*) The percentage of water absorbed in 2 hours and in 24 hours.

DIELECTRIC STRENGTH

Dielectric Strength

14. Except as specified below in Sections 15 to 20, the dielectric strength shall be determined in accordance with the Tentative Methods

of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 - 38 T) of the American Society for Testing Materials.[1]

Electrodes

15. The inner electrode shall consist of a brass rod 3 in. in length, with edges rounded to a ¼-in. radius, and of such diameter that it fits snugly inside the tube to be tested. The outer electrode shall consist of a strip of metal foil 2½ in. in width and long enough to extend around the circumference of the tube.

Test Specimen

16. The test specimens shall be 12 in. in length.

Conditioning

17. (*a*) In the case of materials known to be affected by humidity, conditioning prior to dielectric strength test shall be carried out in accordance with the material specifications applying to the material to be tested.

(*b*) Where the materials are to be used at other than room temperature, their dielectric strength characteristic shall be determined over the operating range of temperature. Prior to test, specimens shall be exposed to each test temperature in a suitable temperature-control chamber for a period in minutes equal to half the wall thickness of the specimen in mils.

Surrounding Medium

18. The tubes shall be tested immersed in oil, maintained at the temperature of the test specimen.

Procedure

19. (*a*) Tests shall be made by either the short-time method or the step-by-step method.

(*b*) In tests made by the short-time method, voltage shall be increased at the rate of 0.5 kv. per sec.

(*c*) In tests made by the step-by-step method, each step shall be of 1 min. duration. The voltage shall be increased in increments as follows:

BREAKDOWN VOLTAGE BY SHORT-TIME METHOD	INCREMENT OF INCREASE OF TEST VOLTAGE
25 kv. or less	1.0 kv.
Over 25 to 50 kv., incl	2.0 kv.
Over 50 to 100 kv., incl	5.0 kv.
Over 100 kv	10.0 kv.

Number of Tests

20. At least five tests shall be made at each test temperature in the short-time method, and at least three tests in the step-by-step

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[1] See p. 1001.

method. Where the range of test temperature is considerable, tests should be made at not less than four temperatures, so that a curve of dielectric strength against temperature may be plotted.

Report

21. Unless otherwise specified, the report shall include the following:

(*a*) The thickness of the specimen,

(*b*) Total volts at each puncture,

(*c*) Volts per mil for each puncture,

(*d*) The average, maximum, and minimum volts per mil for each sample,

(*e*) The temperature of the test specimen,

(*f*) The percentage relative humidity of the surrounding air,

(*g*) The conditioning treatment,

(*h*) The duration of the test,

(*i*) In the step-by-step test, the value of the initially applied voltage and the value of the voltage at each step, and

(*j*) The size and type of electrodes.

DENSITY

Specimens

22. Two specimens shall be tested. Any suitable size specimen may be used. The specimen 1 in. in length used for the water absorption test, Section 11, will be found convenient.

Procedure

23. Any suitable weight-difference apparatus for making readings in water and air, or the weight and dimensions of the specimen may be used as a basis for calculating the density.

Report

24. The report shall express the density in c. g. s. units.

PHASE DIFFERENCE (POWER FACTOR) AND DIELECTRIC CONSTANT

Phase Difference and Dielectric Constant

25. The phase difference and dielectric constant shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 36 T) of the American Society for Testing Materials.[1]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 955 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p 1071.

TENTATIVE METHODS OF TESTING UNTREATED PAPER USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 202 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1924; REVISED, 1925, 1926, 1927, 1928, 1929,
1930, 1932, 1933, 1934, 1936, 1938.

Scope. 1. These methods are intended to apply to untreated paper to be used as an electrical insulator or as a constituent of a composite material used for electrical insulating purposes.

SAMPLING

Sampling. 2. (*a*) From shipments consisting of rolls, a sample of at least 1 sq. yd. in area, cut across the entire width of the roll, shall be taken from every tenth roll in the shipment. From other shipments such as sheets or pads of tape, samples of equivalent area shall be taken in such a manner as to be equally representative of the shipment. In no case shall less than three samples be taken.

NOTE.—It is recommended that several turns of paper from each roll sampled be torn off and discarded before the samples are taken.

(*b*) The tests for physical properties shall be made upon each sample.

(*c*) The tests for acidity, moisture content, ash and for identification of fibers shall be made in duplicate upon portions taken from a composite sample. This composite sample shall be made up of a sufficient number of small pieces, each of approximately 6.5 sq. cm. (1 sq. in.) in area taken in nearly equal amounts from each of the samples taken in accordance with Paragraph (*a*).

(*d*) The required number of samples shall be taken at equal intervals across the sheet, the two end samples being taken at the edges of the sheet after removing any damaged paper. When it is not possible to secure the required number of specimens in this manner in going once across the sheet, the selection across the sheet shall be repeated as many times as necessary until the required number of specimens is secured.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

CONDITIONING SAMPLES

Conditioning. 3. Samples shall be conditioned in air maintained at a relative humidity between 60 and 65 per cent as measured with a sling psychrometer or its equivalent. The temperature of the air shall be maintained as constant as possible at some temperature between the limits of 20 and 30° C. (68 and 86° F.). The samples should remain in the conditioned air for not less than 4 hours prior to the tests and should be supported so as to allow a free circulation around each sample. The following physical tests shall be made in the conditioned air: tensile breaking strength, tearing strength, bursting strength, folding endurance, air resistance, absorption, dielectric strength and thickness.

MOISTURE CONTENT

Apparatus. 4. A weighing bottle, evaporating dish, thermometer, constant-temperature oven, chemical balance and desiccator are necessary for the test. The weighing bottle should be of convenient size, about 65 mm. (2.56 in.) in height and 45 mm. (1.77 in.) in diameter with a wide mouth provided with a ground-glass stopper. The chemical balance should be sensitive to 0.1 mg.

Specimen. 5. The moisture content figure is used to calculate the percentage of acidity, size, and ash of the paper to the bone-dry basis. It shall be determined on 2 to 5-g. samples selected in accordance with Section 2 (*c*).

If the moisture content of the paper as received at the purchaser's works is desired or at any other stated time, it shall be made on the sample taken at the definitely stated time by cutting small pieces of approximately 6.5 sq. cm. (1 sq. in.) in area from the required number of rolls or pads of tape in accordance with Section 2 (*a*) and immediately placed into an air-tight container.

NOTE.—Since paper adjusts itself, as regards moisture content, to the humidity of the surrounding atmosphere in a very short time (2 or 3 minutes), special care must be exercised to transfer rapidly the sample from the roll or bundle to the container and from the container to the weighing bottle.

Procedure. 6. The sample before drying shall be weighed in the tared bottle with the stopper in place. The bottle shall then be placed in the oven at 100 to 105° C. (212 to 221° F.), the stopper removed and laid alongside of the bottle and the contents transferred to the drying dish. After one hour, while still in the oven, the sample shall be replaced in the weighing bottle, and the bottle stoppered and transferred to the desiccator. The stopper should be removed while the bottle cools. When the specimen and the bottle have cooled to room temperature, the stopper shall be replaced and the bottle with its contents weighed. This process shall be repeated at intervals of one hour until the difference in weight between two successive weighings is not more than 0.2 per cent of the weight of the specimen.

NOTE.—The weighing bottle or sample should not be touched with the fingers during this test.

Report. 7. The moisture content shall be expressed:

(*a*) as a percentage of the weight of the dry sample, and
(*b*) as a percentage of the weight of the undried sample.

THICKNESS

Apparatus. 8. The thickness shall be determined in accordance with the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 – 36 T) of the American Society for Testing Materials.[1]

Specimens. 9. Specimens shall consist of the original samples obtained in accordance with Section 2 (*a*).

Number of Measurements. 10. At least five measurements of the thickness shall be taken at regular intervals across the entire width of each specimen.

Report. 11. The average, maximum, and minimum thicknesses obtained on each specimen shall be reported.

WEIGHT

Apparatus. 12. The following apparatus will be required:

(*a*) *Weighing Balance.*—A chemical balance or a specially-constructed sheet-weighing balance are necessary for the test. In case a chemical balance is to be used and if it is not in the conditioned atmosphere, a weighing bottle is also necessary. The weighing device shall be accurate to 0.25 per cent of the load applied.

(*b*) *Knife and Trimming Board.*—A sharp knife or accurate trimming board.

(*c*) *Scale.*—The scale used in measuring the specimen shall be capable of measuring to an accuracy of 0.25 per cent of the smallest dimension to be measured.

Specimens. 13. Duplicate specimens shall be taken from as widely separated portions as possible from each of the samples obtained in accordance with Section 2 (*a*) and conditioned in accordance with Section 3.

Procedure. 14. (*a*) Each specimen while in the conditioned atmosphere (see Section 3) shall be cut accurately to any convenient size and accurately weighed. Specimens of sufficient size to weigh at least from 3 to 5 g. (0.11 to 0.18 oz.) should be taken. If it is not possible to do the weighing in the conditioned atmosphere, the specimen shall be placed in a weighing bottle and tightly stoppered with a ground-glass stopper before being removed from the conditioned atmosphere.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1026 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1196.

(*b*) The weight shall be calculated to and expressed as grams per square meter.

NOTE.—Grams per square meter times 0.00142 equals pounds per 1000 sq. in., from which the weight in pounds per ream of any size can be calculated if desired.

APPARENT DENSITY

Apparent Density.

15. The apparent density shall be calculated from the thickness results obtained from the conditioned specimens (as prescribed in Sections 8 to 11) and the weight (determined in accordance with Sections 12 to 14) by means of the following formula:

$$\begin{array}{c}\text{Apparent Density,}\\ \text{g. per cu. cm.}\end{array} = \frac{\text{Wt., g. per sq. m.}}{\text{Thickness, in.}} \times 0.0000394$$

TENSILE BREAKING STRENGTH

Apparatus.

16. (*a*) A testing machine of the dead-weight pendulum type suitably designed for testing paper shall be used. The machine shall preferably be power driven.

(*b*) The capacity of the machine shall not exceed 113 kg. (250 lb.)

(*c*) The machine shall be graduated to read 1 lb. or 1 kg. or less per scale division for testing paper breaking at 22.7 kg. (50 lb.) or over, and to 0.5 lb. or 0.5 kg. or less for testing paper breaking under 22.7 kg. (50 lb.).

Specimen.

17. From each of the samples selected in accordance with Section 2 (*a*), specimens shall be cut at least ten in the machine direction and if practicable, ten in the cross-machine direction. The specimens shall not exceed 2.54 cm. (1 in.) in width and shall be 25.4 cm. (10 in.) in length with clean-cut edges.

Procedure.

18. (*a*) The ratio of the clearance distance between jaws to the width of the specimen shall not be less than 5 to 1 nor more than 10 to 1.

(*b*) The rate of travel of the movable jaw shall be constant. It shall preferably be 30.5 cm. (12 in.) per minute, but it may be within the limits of 28 cm. (11 in.) and 33 cm. (13 in.) per minute provided it is constant.

(*c*) All readings obtained when the paper breaks at or in the jaws shall be rejected.

Report.

19. (*a*) The results of the machine-direction specimens and the cross-machine-direction specimens shall be reported separately.

(*b*) The results shall be reported in kilograms or pounds together with the width of the specimen in centimeters or inches and also the average thickness.

(*c*) The maximum, minimum, and average breaking load shall be reported for the machine direction and the cross-machine direction.

TEARING STRENGTH

20. The testing machine shall be of the pendulum impulse type so designed as to produce a tear approximately 4.2 cm. (1.66 in.) long. The knife mounted on the machine to cut the slit for the tear shall be maintained sharp. **Apparatus.**

21. The specimens shall be taken from the original samples obtained in accordance with Section 2 (*a*) and shall be cut 6.3 cm. (2.5 in.) in width and at least 6.3 cm. (2.5 in.) in length. Enough specimens shall be cut so that at least five readings in the machine direction and five readings in the cross-direction, if possible, can be obtained for each original sample. **Specimen.**

22. Enough paper shall be torn so that the readings on the machine shall be not less than 10 nor more than 20 g., unless one paper alone yields a reading greater than 20 g., in which case only one paper shall be torn at one time. The specimens shall be so arranged that an equal number of tears originating from opposite edges of the specimens will be produced. Readings obtained when a tear deviates more than 6.3 mm. (0.25 in.) from a straight line, shall be rejected. The readings obtained shall be multiplied by the instrument constant corresponding to the number of sheets torn. **Method.**

23. (*a*) The tearing strengths obtained on the machine-direction specimens and on the cross-direction specimens shall be reported separately in grams. **Report.**

(*b*) The average, the maximum, and the minimum tearing strengths shall be reported for the machine-direction specimens. If possible, similar results shall be reported for the cross-direction specimens.

BURSTING STRENGTH

24. The testing machine shall have a circular flexible diaphragm 6.44 sq. cm. (1 sq. in.) in area. The pressure chamber shall be filled with glycerin or other suitable pressure medium and shall contain no air spaces. The test specimen shall be held in position over the diaphragm in a clamp having a circular hole approximately 6.44 sq. cm. (1 sq. in.) in area so that the diaphragm will force the paper into the hole when pressure is applied under the diaphragm. The pressure exerted on the diaphragm shall be indicated on a dial, graduated to at least 0.23 kg. (0.5 lb.) for papers giving bursting strengths 18 kg. (40 lb.) or under. A dial graduated 0.45 kg. (1 lb.) may be used in testing papers which give higher bursting strengths. The machine may be either hand-operated or power-driven, the latter being preferable. **Apparatus.**

25. If practicable, the specimen shall be so cut from the stock as to permit ten bursting tests on a line across the sheet or roll. **Specimen.**

Procedure. 26. Ten bursts shall be made, five with one side of the paper uppermost and five with the other side uppermost. The testing machine shall be driven at a uniform speed of 120 r.p.m. until the specimen bursts.

Report. 27. The report shall include the average, the maximum, and the minimum results obtained.

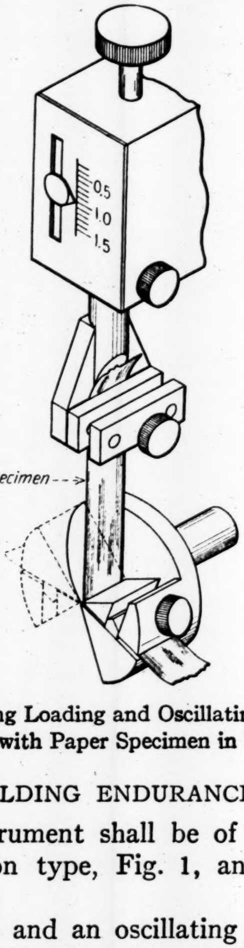

FIG. 1.—Sketch Showing Loading and Oscillating Clamps of Folding Endurance Tester, with Paper Specimen in Testing Position.

FOLDING ENDURANCE

Apparatus. 28. The testing instrument shall be of the adjustable-tension, vertical test-strip position type, Fig. 1, and shall consist of the following:

(*a*) A loading clamp and an oscillating clamp mounted in the same plane. The upper or loading clamp shall have a suitable clamping device, constrained to a vertical movement without rotation. A spring shall be attached to the loading clamp that will give different tensions from 0 to 1.5 kg. dependent upon the displacement. The deflection of the spring when loaded shall not be less than 17 mm. per kg.

(*b*) The lower or oscillating clamp shall be provided with two jaws, each of which terminate in a cylindrical edge near the axis of rotation. The two edges shall be 0.76 mm. ± 0.03 mm. (0.031 in. ± 0.001 in.) in diameter, and not less than 19 mm. (0.748 in.) in length. They shall be parallel to each other and to the axis of rotation. The jaws shall be smooth over all surfaces which come in contact with the paper during the folding cycle. The rotary oscillating movement of the folding clamp shall be such as to fold the paper through an angle of 135 deg. ± 5 deg., to both right and left of the position of zero fold. The folding speed shall be between 140 and 210 double folds per minute.

(*c*) The width of the slot (distance separating folding surfaces) in the oscillating clamp shall be greater than the uncompressed thickness of the paper being tested but shall not exceed it more than 0.25 mm. (0.01 in.).

(*d*) A power-driven device for imparting a rotary oscillating motion of constant period to the folding clamp.

(*e*) A device for registering the number of double folds required to sever the specimen.

Specimens.

29. The specimens shall be taken from the original samples obtained in accordance with Section 2 (*a*) and shall be cut 15 mm. (0.59 in.) in width and with a length such as to insure a firm grip in the jaws without buckling. Not less than 10 strips cut with the machine direction parallel with the strip length and, if practicable, 10 strips cut in the cross-machine direction shall be tested. The specimens shall be conditioned in accordance with Section 3.

Procedure.

30. (*a*) The oscillating clamp shall be placed in the position of zero fold. A 1.0-kg. weight shall be placed on top of the plunger and the plunger clamped in position when depressed under this load. The specimen shall then be clamped firmly and squarely in the jaws with the surface of the specimen lying wholly within one plane and not touching the jaw mounting-plate. The specimen shall be handled by the ends and not touched with the hands in the region which is to be folded. The specified tension shall then be applied to the test strip by releasing the plunger. If the reading of the load indicator has changed, it shall be reset by means of the adjusting screw to agree with the reading obtained when the weight was applied. The strip shall be folded at a uniform rate until it is severed at the crease. The number of double folds required to sever the specimen shall be recorded.

(*b*) If a tension of 1.0 kg. is too great or too little to afford practical test results, a greater or lesser tension than 1.0 kg. may be used.

Calibration. 31. (*a*) All working parts shall be in good condition, well oiled, and in proper adjustment. Particular care shall be given to make certain that the folding edges are free from rust or dirt.

(*b*) The plunger friction shall be measured by determining the additional load required to move the plunger perceptibly when displaced under a load of 1.0 kg. or the load tension used in testing. The additional load required shall not be greater than 25 g.

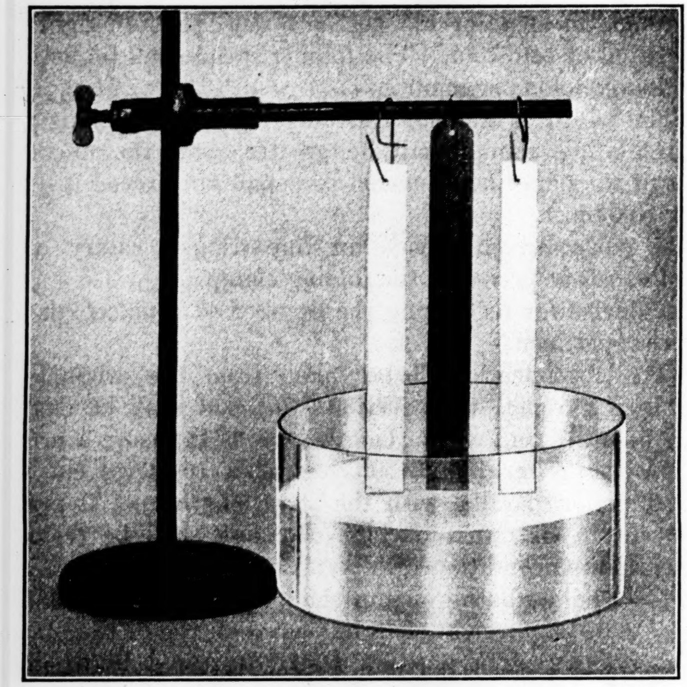

FIG. 2.—Apparatus for Absorption Test.

(*c*) The change in tension due to eccentricity of rotation of folding edges shall be measured as follows: Place a test strip of strong paper, cut in the machine direction, of the proper thickness in the tester in the same manner in which a folding test would be made, and apply a tension of 1.0 kg. or that used in the testing. Rotate the lower jaw slowly throughout the entire folding cycle and measure the maximum change in displacement of the plunger to an accuracy of 0.10 mm. (0.004 in.). The amount of load required to produce the same displacement shall not be greater than 35 g.

Report. 32. The report shall include the number of tests, and the average, the maximum, and the minimum results for both of the principal directions of the paper. The results shall be expressed as M.I.T. double folds at the tension used. Tests run on strips having their length in the machine direction shall be designated as those of "machine direction." In reporting average results, all digits after the first two shall be rounded to zeros.

ABSORPTION

(RISE OF WATER)

33. A suitable container and support for specimens and scale is shown in Fig. 2. **Apparatus.**

34. Ten strips 2.5 cm. (1 in.) in width and at least 12.5 cm. (5 in.) in length shall be cut from the samples obtained in accordance with Section 2 (*a*), five being cut parallel with the machine direction of the paper and five being cut parallel with the cross-direction of the paper. **Specimens.**

35. The specimens shall be suspended vertically with one end dipping 3.2 mm. (0.125 in.) in distilled water at room temperature. **Procedure.**

After five minutes of suspension, the rise of the water in the paper above the water level shall be noted. The rise may be measured by reading directly from the scale the height of absorption.

36. The rise of water shall be reported in millimeters to the nearest 3 mm. or in inches to the nearest $\frac{1}{8}$ in. **Report.**

AIR RESISTANCE

37. (*a*) The instrument shall consist of two aluminum open-top cylinders, one of which is inverted and slides into the other which is fixed. The movable cylinder shall be provided with a circular aperture in the closed end and a flat ring clamp for holding the paper specimen across this aperture. **Apparatus.**

(*b*) The fixed cylinder shall be 25.4 cm. (10 in.) in height and shall have an external diameter of 8.60 cm. (3.38 in.) and an internal diameter of 8.25 cm. (3.25 in.). Four slender bars, each 18.5 cm. (7.3 in.) long, 3 mm. (0.12 in.) wide and approximately 1.5 mm. (0.06 in.) thick shall be mounted vertically and equi-distantly on the inner surface of the fixed cylinder to act as guide tracks for the movable cylinder. The movable cylinder shall be graduated in units of 50 ml. and shall have a total range of 350 ml. It shall be 25.4 cm. (10 in.) high and shall have an external diameter of 7.62 cm. (3.00 in.) and an internal diameter of 7.35 cm. (2.90 in.). It shall weigh, including the flat ring clamp and the two knurled nuts, 567 g. ± 0.5 g. (20 oz. ± 0.018 oz.). The movable cylinder and the flat ring clamp shall have a concentric circular aperture of 6.44 sq. cm. (1.00 sq. in.) in area. When this aperture is too large for the specimen a similar movable cylinder and flat ring clamp having a concentric circular aperture of 1.61 sq. cm. (0.25 sq. in.) in area shall be used.

NOTE.—Results obtained with apertures of different areas are not directly proportional to the areas of the apertures. The proportionality factor must be determined by experiment.

Specimen. 38. The specimens shall be not less than 3.5 cm. (1.36 in.) nor more than 5.1 cm. (2.0 in.) in width cut from the original samples, taken in accordance with Section 2 (*a*) and shall be as long as the width of the original roll of paper. If the specimens are selected from pads of tape they shall be not less than 2.1 cm. (0.81 in.) nor more than 5.1 cm. (2.0 in.) wide and at least 30 cm. (12 in.) long. There shall be as many specimens as there are original samples.

Procedure. 39. The fixed cylinder shall be placed on a rigid support so that its sides are vertical. A lubricating oil with viscosity of 60 to 70 seconds Saybolt at 37.8° C. (100° F.) shall be placed in it to a depth of 12.7 cm. (5 in.). The specimen (one thickness only) shall be secured tightly under the clamp on the movable cylinder completely covering the aperture. The movable cylinder is then floated on the lubricating oil. The time required for the displacement of a certain amount of air shall be noted with a stop-watch. If possible, the amount of air displaced should be such that the time of displacement is not less than 20 seconds. The apparatus with its content of lubricating oil shall be at the temperature of the conditioning room when the readings are taken. The time in seconds required for the displacement of 100 ml. (6.1 cu. in.) of air through a circular area (one side only) of 6.44 sq. cm. (1 sq. in.) of the paper is known as the air resistance of the paper.

NOTE.—The clamp shall be tested for leakage by substituting a piece of tinfoil 0.05 mm. (0.002 in.) in thickness for the paper and testing in the manner described above. When so tested, the leakage shall not exceed the rate of 50 ml. in five hours.

The proper procedure for clamping the specimen or tinfoil is to turn both knurled nuts down onto the clamp simultaneously. If only one nut at a time is turned down, the clamp will not fit flat on the specimen and will consequently have an avoidable leak.

Oil is used in preference to distilled water because it does not corrode aluminum whereas distilled water does.

Precautions should be taken to avoid subjecting the apparatus to vibration as this condition would increase the rate of air displacement.

Report. 40. The report shall include the following:

(*a*) the number of seconds required for the displacement of 100 ml. (6.1 cu. in.) of air;

(*b*) the area of paper through which the air was displaced;

(*c*) the thickness of the paper as obtained under Sections 8 to 11;

(*d*) the room temperature.

NOTE.—The following values show the probable accuracy obtainable in the air-resistance tests:

AIR RESISTANCE	ACCURACY
40 seconds	± 5 per cent
100 seconds	± 6 per cent
200 seconds	± 8 per cent
300 seconds	± 10 per cent

FIBER COMPOSITION

Fiber Composition.

41. The percentage of various fibers contained in samples shall be determined in accordance with the Standard Methods of Analysis of Roofing Felt for Fiber Composition (A.S.T.M. Designation: D 272) of the American Society for Testing Materials.[1]

ASH

Apparatus.

42. A suitable crucible such as platinum, nickel or porcelain, a balance sensitive to 0.1 mg., and a desiccator are necessary for the test.

Specimen.

43. Not less than 2 g. of dry, finely-divided paper from the "moisture determination" sample as obtained in accordance with Section 6 shall be used.

Procedure.

44. The sample shall be transferred rapidly from the weighing bottle containing the dried sample into the crucible. The weighing bottle shall immediately be re-stoppered and re-weighed, and the exact weight of the sample obtained by taking the difference in weights of the weighing bottle and the sample. The sample shall be completely ignited in the crucible, preferably in a muffle furnace, all precautions being taken to prevent loss of ash or sample. The residue of incombustible mineral matter (ash) shall be desiccated, cooled and weighed, and the amount computed as a percentage of the weight of the dried sample.

Report.

45. The amount of ash shall be reported as a percentage of the weight of the dry sample (see Section 7 (*a*)) and also as a percentage of the weight of the undried sample (see Section 7 (*b*)).

ACIDITY OR ALKALINITY

Apparatus.

46. (*a*) A hot water bath, electric hot plate, motor with stirrer, 250-ml. wide-mouth acid-resistant and alkali-resistant glass[2] Erlenmeyer flasks, thermometer graduated to 1 C., covering the range from 50 to 100 C., 10-ml. burette graduated to 0.05 ml., and a suction filtering apparatus, are required for the test.

(*b*) The stirrer shall be made of brass, chromium plated to render it acid and alkali resistant, and shall be constructed as shown in Fig. 3.

Special Solutions Required.

47. (*a*) *Distilled Water.*—Adjust the distilled water used in making the extractions to a pH of 7.0 to 8.0 when free of carbon dioxide.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1162.

[2] **Pyrex glass has been found very satisfactory for this purpose.**

Carbon dioxide can be eliminated by boiling or by bubbling nitrogen through the solution during the pH measurement or titration.

The following method of adjusting the pH of water to be used in making extractions is recommended: Carry out a titration on 100 ml. of the water according to the prescribed procedure under "blank titration." If more than 0.10 ml. of 0.005 *N* alkali solution is required to obtain an end point with phenolphthalein, adjust the pH of the water to be used by adding the calculated amount of alkali so that the blank titration on 100 ml. is 0.10 ml. or less of 0.005 *N* alkali, (that is, the water used should be neutral or only slightly acid to the phenolphthalein indicator).

(*b*) *Standard Alkali Solution* (*Approximately 0.005 N*).—To standardize, prepare 250 ml. of 0.005 *N* potassium acid phthalate solution by dissolving 0.2552 g. of the dried salt (National Bureau of Standards) in water and making up to the mark in a 250-ml. volumetric flask at 20 C. (Do not dry the salt at a temperature above 125 C.) Pipette 25 ml. of this solution into a 250-ml. flask. Add 25 ml. of water and 5 drops of phenolphthalein solution. Pass nitrogen through the solution for 10 min. Titrate in a closed system with the standard sodium hydroxide solution to the first permanent pink shade. If preferred, the potassium acid phthalate solution may be heated to boiling and titrated immediately, taking care that the temperature does not fall below 80 C. during the titration. Run three samples in the above way at each standardization of the alkali. Determine a blank on the same volume of distilled water and phenolphthalein and deduct from the titration obtained above. Calculate the normality by the following formula:

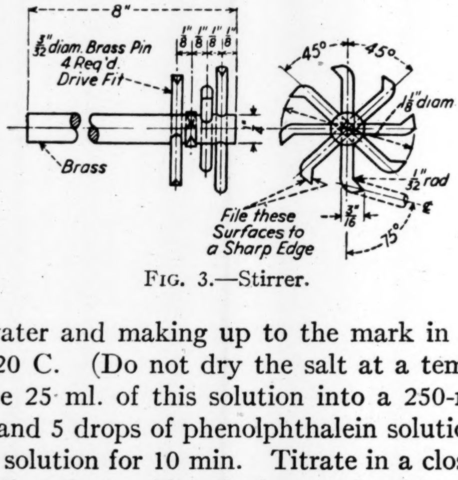

FIG. 3.—Stirrer.

$$\text{Normality} = \frac{25 \times 0.005}{\text{milliliters of NaOH required}}$$

(*c*) *Sulfuric Acid* (*Approximately 0.005 N*).—Determine the alkali equivalent of the acid as follows: Transfer 10 ml. of the acid to a 250-ml. Erlenmeyer flask and dilute with 100 ml. of distilled water.

Titrate in a closed system or at the boiling point with the standard alkali solution as described in Paragraph (*a*) for the standardization of the alkali solution. Determine a blank on the same volume of distilled water and phenolphthalein and deduct from the titration obtained above. Calculate the alkaline equivalent of the acid as follows:

$$\text{Alkali equivalent (in milliliters) to 1 ml. of } H_2SO_4 = \frac{\text{milliliters of alkali required (corrected)}}{\text{milliliters of } H_2SO_4 \text{ taken}}$$

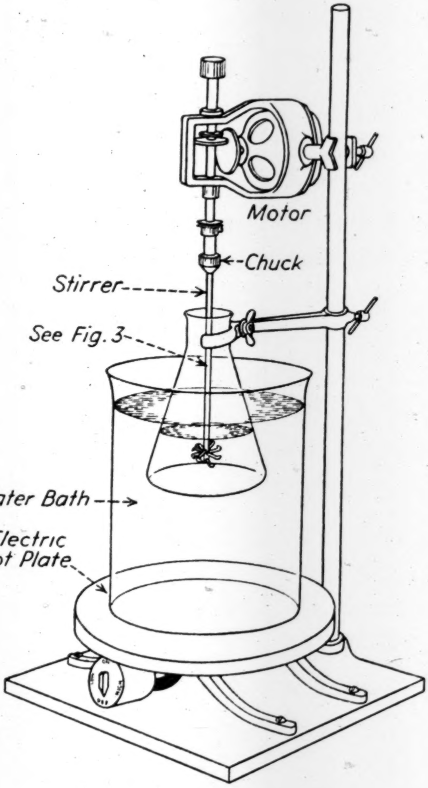

FIG. 4.—Extraction Apparatus.

(*d*) *Phenolphthalein Solution.*—Dissolve 0.5 g. of phenolphthalein in 100 g. of c.p. ethyl alcohol (95 per cent).

Sample. 48. From the original samples obtained in accordance with Section 2(*a*), a composite sample of at least 5 g. shall be cut into small pieces, approximately 1-cm. (0.4-in.) square. The sample shall be thoroughly mixed and, during preparation, contamination by handling shall be avoided.

Procedure. 49. (*a*) One gram of the composite sample shall be placed in a

250-ml. Erlenmeyer flask and 100 ml. of boiling, distilled water added. The flask shall then be clamped in position in a boiling water bath so that at least one-half of the flask shall be immersed in the water bath. During the stirring, the temperature of the contents of the flask shall remain at least as high as 95 C. The stirrer shall be mounted so that the blades are within 1 cm. (0.4 in.) of the bottom of the flask. The assembled extraction apparatus is shown in Fig. 4. The stirrer shall be driven at a speed of 4000 to 5000 r.p.m. for 5 min. At the end of this period the samples should have been thoroughly pulped. For paper unusually difficult to pulp, the period of stirring shall be increased to 10 min.

(*b*) Immediately after the sample has been pulped, the contents of the flask shall be filtered rapidly into another 250-ml. Erlenmeyer flask without washing.

NOTE.—It is important that the filtration of the extract be accomplished as promptly as possible after disintegration. To ensure rapid filtration, filter, using suction, through a No. 42 Whatman paper (which has been washed twice with 100-ml. portions of hot distilled water) on a Büchner funnel. Use a suction bell jar and collect the filtrate in the Erlenmeyer flask.

(*c*) The filtered extract shall be titrated as described in Section 47(*a*) for standardizing the alkali solution. If the extract is acid, it shall be titrated with 0.005 *N* NaOH, using 5 drops of phenolphthalein solution as indicator. The appearance of a definite pink color indicates the end point. If the extract is alkaline, a small excess of 0.005 *N* H_2SO_4 shall be added and the titration then completed with 0.005 *N* NaOH as described above.

(*d*) The titration obtained in Paragraph (*c*) shall be corrected for the blank error. This correction shall be determined by running a blank in parallel with the actual determination using a volume of pure distilled water equal to that of the extract at the end point. If the solution is acid, this blank correction shall be subtracted from the volume of alkali used; if alkaline, the correction shall be added:

Calculation.

50. (*a*) The acidity or alkalinity shall be calculated as follows.

$$\begin{array}{c}\text{Milliequivalents of}\\ \text{acid or alkali per gram}\\ \text{of paper}\end{array} = \frac{\text{milliliters of NaOH required (corrected)} \times \text{normality}}{\text{sample weight in grams}}$$

(*b*) The results shall be expressed as the number of milliequivalents of acid per gram if the extract is acid, or as the number of milliequivalents of alkali per gram if the extract is alkaline, the number of milliequivalents being based on the weight of the air-dry sample.

Number of Tests.

51. At least two samples shall be carried through the foregoing procedure. If, in duplicate samples, the titrations do not agree within 0.10 ml., the determinations shall be repeated.

SURVEY FOR CONDUCTING PATHS

Scope. 52. The survey for conducting paths in untreated insulating paper is a test to determine the number of conducting paths in the paper as indicated by the number of electrical breakdowns (or points of excessive current flow in thin papers (see Section 52 (*b*)) when relatively large areas of the paper are subjected to a voltage somewhat lower in value than the dielectric strength of the paper when tested in accordance with the short-time test described in the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 - 38 T) the American Society for Testing Materials.[1]

Apparatus. 53. (*a*) The survey shall be made by passing a specimen of the paper between metallic electrodes across which a voltage is impressed. The arrangement of the apparatus may be of any convenient form which will allow the application of the required voltage to a specimen of relatively large area, and will allow the electrical breakdowns to be indicated so that the number of these may be counted.

(*b*) For papers having a thickness of 0.038 mm. (0.0015 in.) or less it has been found preferable to use a detecting device such as a telephone receiver to detect the excessive current through the conducting paths rather than to allow complete electrical breakdown of the specimen. Also, it is preferable to pass one electrode over the paper rather than to draw the paper through between the electrodes.

Specimen. 54. The specimen shall be of relatively large area, such as a pad of tape, or a sheet from each sample of paper (see Section 2 (*a*)).

Procedure. 55. The survey shall be made by passing the specimen between the metallic electrodes at a speed of 30 to 60 ft. per minute. The voltage impressed across the electrodes shall be 100 volts per mil thickness of the specimen if alternating voltage is used, or 141 volts per mil thickness of the specimen if direct voltage is used.

NOTE 1.—If the voltage values specified above prove inconvenient of application, a lower voltage may be used, in which case it is necessary to establish a relationship between the conducting paths at this voltage and at the specified voltage. A lower value of conducting paths will be obtained at the lower voltage.

NOTE 2.—A description of equipment and a procedure which have been found suitable for making this survey of conducting paths in different thicknesses of paper appears in the Appendix.

Report. 56. The report shall include the following:

(*a*) The total number of conducting paths and the conducting paths per unit area.

(*b*) The length, width, area, and thickness of the specimen.

(*c*) The voltage applied expressed in volts, and volts per mil thickness of specimen.

(*d*) The speed of the paper.

---

[1] See p. 1001.

DETERIORATION

Apparatus. 57. (*a*) *Baking Oven.*—An electrically-heated oven, equipped with an efficient means of circulating air *within* or *through* the heated chamber, and a suitable fixture upon which the paper specimens may be mounted, shall be used. In case the air is circulated *within* the body of the oven, for example by fan, it is required that the fixture upon which the specimens are mounted be a turntable rotating within the oven at a speed of about 20 r.p.m., so that the specimens shall be uniformly exposed to the oven conditions. In the case of heated air circulating *through* the oven, the fixture holding the specimens may be stationary but it is essential that it shall be mounted so as to be at least 4 in. from the oven walls at any point to permit adequate circulation in all parts of the oven, and the design should be such that there shall be an air velocity of at least one foot per second through the oven.

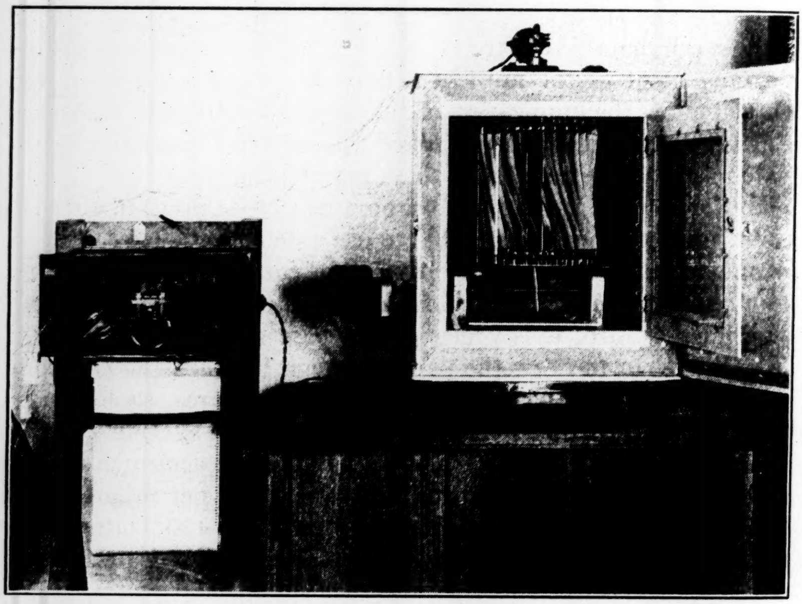

FIG. 5.—Baking Oven Equipped for Circulating Air Within the Oven.

(*b*) *Testing Equipment.*—In addition to the oven it is necessary to provide testing machines for making physical measurements on the baked specimens. The tests may be tensile breaking strength, tearing strength, folding endurance, or brittleness.[1]

---

[1] Another sensitive test for paper deterioration is brittleness strength. This does not appear in the method, but will be included as soon as the test is developed by the committee.

58. The specimens shall be at least ½ in. in width and at least 12 in. in length, and shall be cut from samples obtained in accordance with Section 2 (*a*). At least five groups of 5 specimens each shall be selected for each type of physical test noted in Section 57 (*b*). These groups of specimens shall be selected from the gross sample in some rational manner, so as to represent any known or suspected differences in the quality of the product. **Specimens.**

59. (*a*) The specimens shall be mounted on the fixture as shown in Figs. 5 and 6. In the case of the rotating turntable, Fig. 5, the specimens shall be mounted at such an angle that they will assist, fan-like, in stirring the air within the oven. In the case of a stationary scheme of mounting, Fig. 6, the specimens shall be mounted vertically. The rows of clips supporting the specimens, top and bottom, should be set alternately at 45-deg. angles across the oven so that the air flowing horizontally through the oven would pass between these staggered rows, turbine fashion, and assist in keeping the temperature uniform in all parts of the oven. **Baking.**

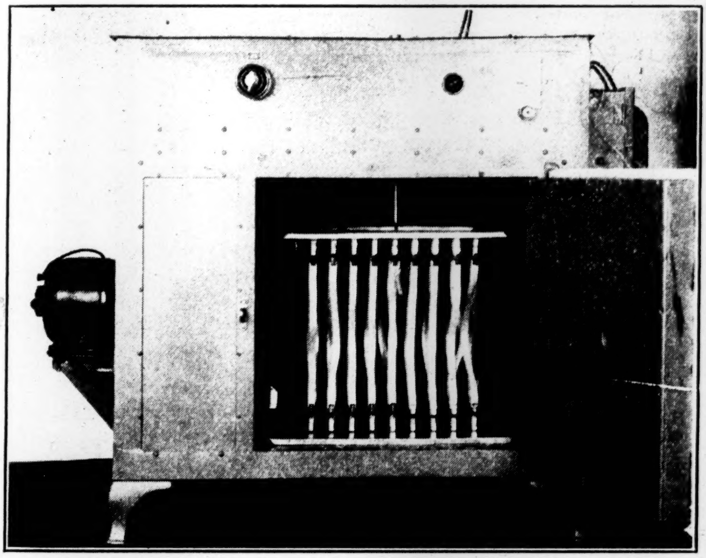

FIG. 6.—Baking Oven Equipped for Circulating Air Through the Oven.

(*b*) The fixture, readily removable from the oven for mounting the specimens, shall be put in place, and the oven, previously brought to 135° C., shall be closed. Air shall be circulated, as previously indicated, and the temperature shall be maintained at 135° C. ± 2° C.

for 96 hours.[1] It is imperative that the differences in temperature in different parts of the oven shall not exceed 2° C.

Conditioning and Testing.

60. The baked specimens shall be removed from the mounting fixture, care being taken not to damage the strips, and shall be conditioned in a humidity room at 60 to 65 per cent relative humidity and at a temperature of 68 to 86° F., for a period of 4 hours. They shall then be tested in this conditioned room for tensile breaking strength tearing strength, folding endurance, or brittleness.[2]

Report.

61. The maximum, minimum and average values shall be reported for each type of test used.

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[1] These temperature and time conditions are satisfactory for the more stable types of cable insulating papers. Less severe conditions should be used for other insulating papers and these will be included as soon as they are developed by the committee.

[2] Another sensitive test for paper deterioration is brittleness strength. This does not appear in the method, but will be included as soon as the test is developed by the committee.

APPENDIX

DESCRIPTION OF APPARATUS FOR A SURVEY FOR CONDUCTING PATHS IN UNTREATED INSULATING PAPERS

Equipment and procedure which have been found to be suitable for making the survey of conducting paths for different thicknesses of paper are as follows:

For Paper Having a Thickness of 0.038 mm. (0.0015 in.) or Under.—For paper having a thickness of 0.038 mm. (0.0015 in.) or under, a brass plate, a brass roller with an insulated handle, a pair of telephone receivers having a total resistance of 3000 ohms, a resistor of 80,000 ohms, and a source of direct voltage of 110 volts is used in this test. The brass plate is 31.8 cm. (12.5 in.) in width and 38.7 cm. (15.25 in.) in length and is machined and polished until its surface is level and smooth. The brass roller has a diameter of 5.08 cm. (2 in.) and a face of 2.54 cm. (1.00 in.) in width. The surface of the roller should be accurately cylindrical and polished so that it will always make a line contact when it is rolled over the brass plate in any direction. A brass plate which will warp the least is best obtained by casting a plate at least 2.54 cm. (1.00 in.) in thickness and dressing down the surface to the desired smoothness.

The size of the specimen is 38.7 cm. (15.25 in.) square, and is prepared for test as follows: Using a soft pencil (No. 2) and bearing lightly, mark off 12 swaths on each specimen (see Fig. A1). Each swath is 2.54 cm. (1 in.) in width and 30 cm. (12 in.) in length. The swaths are spaced 0.63 cm. (0.25 in.) from each other. The specimen is then placed on the brass plate in such a manner that the ends of all the swaths are spaced 0.63 cm. (0.25 in.) from the edges of the brass plate. The specimen may be held in position by means of two weights as shown in Fig. A1.

Connect the brass roller to one pole of the 110-volt circuit. Connect the brass plate, the 80,000-ohm resistance and the telephone receivers in series to the other pole of the 110-volt circuit. (See Fig. A1.) Run the brass roller once over each swath slowly in succession and count the clicks audible in the telephone receivers. Each click is considered to represent a conducting path. The total number of clicks counted on all the specimens divided by the total area of all the swaths of all the specimens, is the number of conducting paths per unit area.

For Paper Having a Thickness Greater Than 0.038 mm. (0.0015 in.) and Less Than 0.76 mm. (0.030 in.).—For paper having a thickness greater than 0.038 mm. (0.0015 in.) and less than 0.76 mm. (0.030 in.) a transformer with regulating equipment to give the required voltage, a voltmeter, a source of alternating voltage, a brass plate and a set of brass rollers are used. The brass plate is 15.2 cm. (6 in.) in width and 122 cm. (48 in.) in length and is machined and polished until its surface is level and smooth. Each brass roller has a diameter of 3.81 cm. (1.5 in.) and a face 2.54 cm. (1 in.) in width. The surface of each brass roller is accurately cylindrical and polished so that it makes a line contact when it is placed in its position on the brass plate. The brass rollers are mounted in two parallel rows above the brass plate in such a manner as to permit each individual roller to be raised away from the brass plate or lowered to make a line contact with it. The rollers in each row are spaced and have a common geometric axis. The axes of the two rows of rollers are parallel to each other and also to the long edges of the brass plate. The rollers in one row are staggered with respect to the rollers in the other row so that the surface of paper passing under the first row of rollers will be partially overlapped by the second row of rollers (see Fig. A2). The entire surface of the paper makes contact with the rollers at least once and a part of the surface of the paper will make contact twice. The rollers and plate are adequately insulated from each other.

The specimen is 7.61 meters (25 ft.) in length. Place the specimen between the brass plate and the brass rollers. During the test period the moisture content of the specimen shall not exceed 7 per cent. Lower the brass rollers to make contact with the specimen. Before connecting the transformer to the source of alternating voltage, connect the brass plate to one of the high-voltage terminals of the transformer, and the brass rollers, in multiple, to the other high-voltage terminal of the transformer. Then connect the low-voltage side of the transformer with its regulating equipment to the source of alternating voltage. Adjust the voltage between the brass plate and the brass rollers to the required value (100 volts per mil thickness of the specimen). Pass the specimen along between the rollers and the plate at a speed not to exceed 9.75 m. (32 ft.) per minute and count the number of holes burned in the specimen. Each hole shall be considered as representing a conducting path. The total number of holes counted in all the specimens divided by the total area covered (one side only) of all the specimens is the number of conducting paths per unit area.

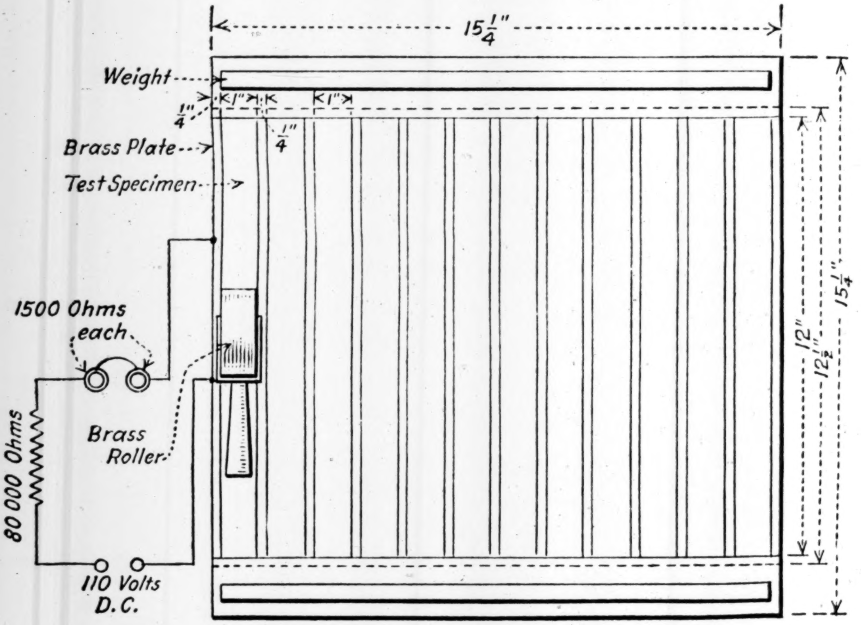


FIG. A1.—Arrangement of Apparatus for Surveying Thin Paper for Conducting Paths.

NOTE.—*Caution:* Disconnect the transformer from the source of alternating voltage before proceeding to place the next specimen between the brass plate and brass rollers.

Specimens in the form of pads of tape may be conveniently tested with an apparatus somewhat similar to the above wherein the pad is mounted on a suitable drum and the entire length of the paper in the pad rerolled on to a second drum, the paper meanwhile passing between two cylindrical rollers across which voltage is applied. The lower roller is somewhat wider than the tape and the upper roller somewhat narrower to prevent arcing through the air between the rollers. The conducting paths are counted by means of a relay and mechanical counter.

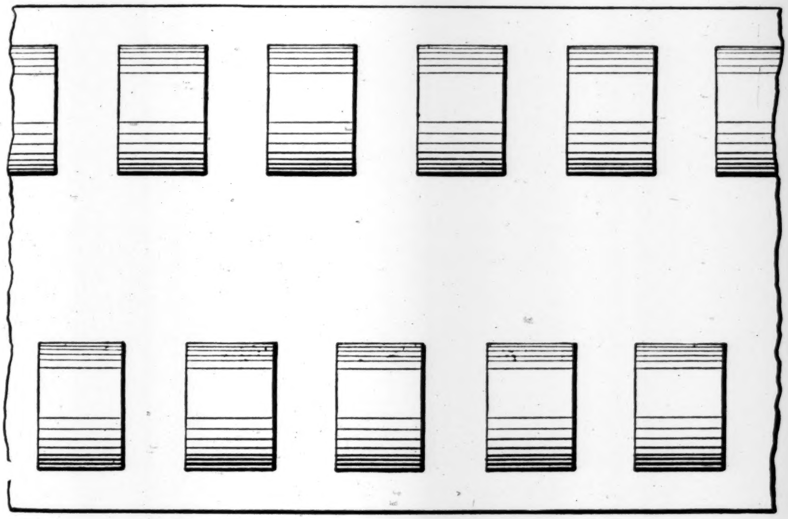
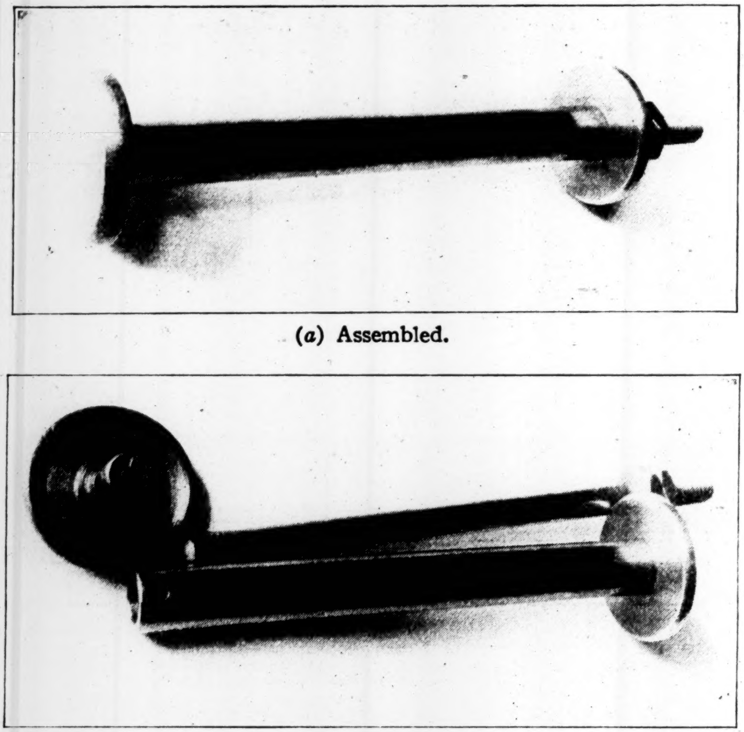


FIG. A2.—Arrangement of Brass Rollers Used in Surveying Paper for Conducting Paths.

For Paper Having a Thickness of 0.76 mm. (0.030 in.) or Over.—For paper having a thickness of 0.76 mm. (0.030 in.) or over a transformer with regulating equipment to give the required voltage, a voltmeter, a source of alternating voltage, a brass plate and a set of disc electrodes are used. The brass plate is 20.3 cm. (8 in.) in width and 122 cm. (48 in.) in length and is machined and polished until its surface is level and smooth. The contact surface of the disc electrodes has a diameter of 3.81 cm. (1.5 in.) with edges rounded to a curvature of 0.64 cm. (0.25 in.) radius. Figure A3 (*a*) shows a convenient design and Fig. A3 (*b*) shows the parts unassembled. The contact surface of each electrode is machined and polished until it is level and smooth and makes an accurate surface contact when it is placed in its position on the brass plate. The disk electrodes are mounted in four parallel rows above the brass plate in such a manner as to permit each individual electrode to be raised away from the brass plate or lowered to make an accurate surface contact with the plate. The four rows of electrodes are parallel to the long edges of the brass plate. The electrodes in one row are staggered with respect to the electrodes in each of the other rows so that the surface of a sheet of paper passing under the electrodes of the first row will be partially overlapped by the electrodes in the second row. Likewise, the surface of paper passing under the electrodes of the second row will be partially overlapped by the electrodes in the third row. And finally, the surface of paper passing under the electrodes of the first and third rows will be partially overlapped by the electrodes in the fourth row. When a sheet of paper has been passed under these four rows of electrodes, the entire surface of the paper will have made contact with the electrodes at least once and a part of the paper surface will have made contact twice. The electrodes and the brass plate should be adequately insulated from each other.



(*a*) Assembled.

(*b*) Unassembled.

FIG. A3.—Disk Electrode for Surveying Paper Over 0.76 mm. in Thickness for Conducting Paths.

The specimen is 7.61 meters (25 ft.) in length. Place the specimen between the disk electrodes and the brass plate. Lower the electrodes to make contact with the specimen, and then proceed as described above for paper 0.038 mm. (0.0015 in.) to 0.76 mm. (0.030 in.) in thickness, except that the specimen is passed between the electrodes and the brass plate at a speed not to exceed 11 m. (36 ft.) per minute. The voltage between the plate and the electrodes should be 100 volts per mil thickness of the specimen.

TENTATIVE METHODS OF TESTING PIN-TYPE, LIME GLASS INSULATORS[1]

A.S.T.M. Designation: D 468 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.[2]

Scope

1. These methods are intended to apply to the testing of pin-type, lime glass insulators used for primary and secondary power distribution.

SAMPLING

Sampling

2. (*a*) Sampling for purpose of these test methods shall be as specified in the following Paragraphs (*b*) and (*c*). The insulators shall be selected in such a manner as to be representative of the lot. Sampling for testing by the purchaser on individual shipments shall be by mutual agreement between the purchaser and the seller.

(*b*) Every insulator shall be checked during production for the presence or absence of structural defects. One insulator in each fifty shall be gaged. Thermal shock tests and mechanical strength tests shall be made on at least one insulator selected at random every hour during production, but not less than one out of every 1000 insulators; tested insulators shall be discarded.

(*c*) For the electrical flashover and dielectric strength tests (Section 8) specimens representative of the product shall be tested and certified by a commercial or institutional testing laboratory.

ROUTINE TESTS

3. Routine tests shall consist of visual inspection for physical and structural defects; gaging for pin-hole formation; thermal shock test for homogeneity and uniformity of annealing; and, mechanical test for structural strength, applied in that order. Thermal shock and mechanical strength tests shall be made only on insulators which are free from objectionable physical and structural defects and have passed visual inspection.

Structural Defects

4. The finish of the insulators as indicated by the presence or absence of structural defects, such as cracks, chips, folds, and stones, or other visible flaws covered in the purchaser's product specifications shall be determined by visual inspection.

Chips are defects caused by the fracture and complete removal of a portion of the insulator.

Folds are linear indentations of the surface of the insulator caused by the meeting and partial welding of a reentrant portion of a surface which has been partially chilled in some previous stage of the process of manufacture.

Stones are foreign, solid, inorganic matter completely or partially surrounded by glass usually consisting of particles of refractory material, crystalline products due to combination of refractories and glass batch constituents, particles of an incompletely melted batch, or products of devitrification of the glass.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] Revision accepted by Committee E-10 on Standards, August 25, 1938.

Gaging Threads

5. The gaging test is intended to determine whether the pin hole is properly formed with smooth and uniformly pitched threads. The insulator shall be screwed home on the gage specified (see Appendix I), and when so seated observation shall be made of the clearance in inches between the top end of the gage and the crown of the insulator. There shall be no perceptible play or rocking of the insulator when seated on the gage. The number of turns necessary to release the gage shall be determined by holding the insulator upside down and counting the revolutions of the insulator required before it can be disengaged from the gage.

Thermal Shock

6. (*a*) The thermal shock test consists in transferring the insulators from a hot-water bath to a cold-water bath and then from a cold to a hot bath (Note 1).

NOTE 1.—The thermal shock of 70 F. (21 C.) from the hot to the cold bath is a check for homogeneity of the glass and freedom from objectionable localized stresses, while the cold to hot shock of 100 F. (38 C.) serves to enlarge and make more obvious incipient surface imperfections.

(*b*) *Apparatus.*—Two water baths are required. One bath shall be equipped with means for heating the water unless a supply of preheated water is used. The baths may be made of planking. If metal baths are employed they shall be insulated with 1 in. of cork or equivalent material to prevent excessive cooling at the sides. The heating supply shall be so placed that the water bath will be heated uniformly (Note 2). The volume of the water in each bath shall be at least 50 times the volume of the glass immersed. A rack arranged to keep the units separated from each other and to support them in a substantially horizontal position shall be provided for immersing the insulators. There should be holes in the base of the rack and in the sides between the slats so as to permit a uniform transfer of the insulators without causing excessive agitation at the time of immersion. There shall be a clearance of at least 3 in. between the sides of the rack and the sides of the bath. Standard thermometers, preferably partial-immersion thermometers graduated in degrees Fahrenheit and conforming to the Standard Specifications for A.S.T.M. Partial-Immersion Thermometers for General Use, −20 to +150 C., 0 to +300 F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials,[1] shall be available for checking the temperatures of the baths.

(*c*) *Procedure.*—The water shall be stirred and then the temperature of each of the water baths shall be checked for uniformity by noting the temperature at various places in the bath. The insulators shall be submerged in the bath by means of wooden racks and in such manner as will cause the minimum disturbance of the water. They shall be submerged to mid-depth of the bath to permit the filling of the pin cavity and between petticoats. At least four insulators of each type shall be tested at one time, half without pins and half with standard pins, of the type to be used, screwed tightly into the pin holes. The pins shall have well-formed threads, and when threads show wear the pins shall be discarded.

NOTE 2.—The bath should not be heated by any method which applies heat directly to the walls of the bath such as heating the bath on a hot plate, and no heat is to be added during the period of immersion. If ice is used to adjust the temperature of the cold bath, it shall be removed from the bath and the water stirred before immersing the insulators.

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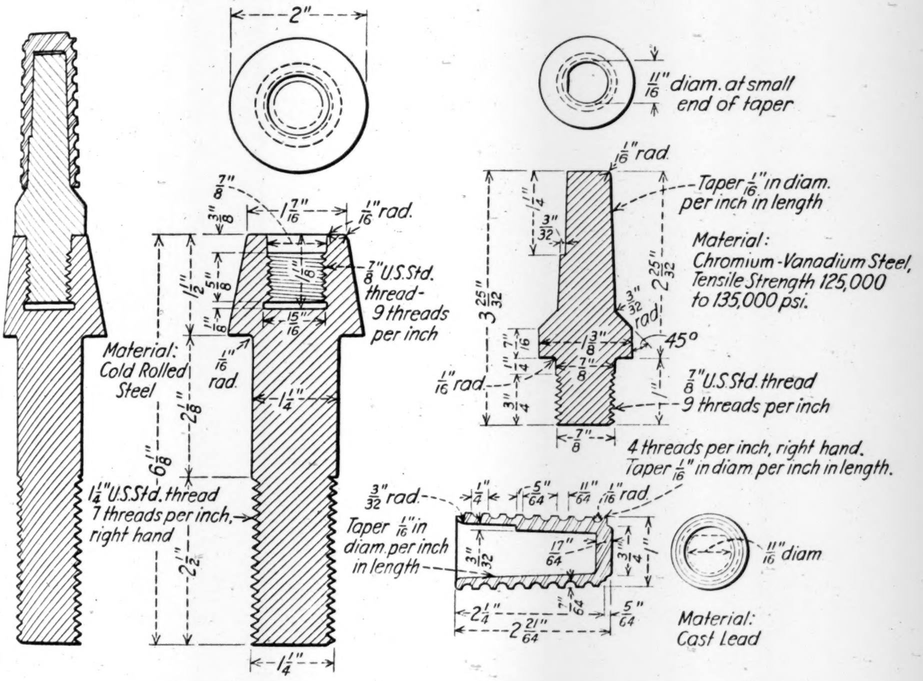
[1] 1936 Book of A.S.T.M. Standards, Part II, p. 1403.

(*d*) *Hot to Cold Shock.*—The insulators shall be placed in the hot-water bath for 10 min. and then immersed 5 sec. later in the cold-water bath, left therein for 10 min., and then removed and examined. The temperature of the water in the hot bath shall be between 120 and 140 F. (49 and 60 C.), and the temperature difference between the hot and the cold baths at the time of immersion shall be 70 ± 2 F. (39 ± 1 C.).

(*e*) *Cold to Hot Shock.*—The same insulators shall then be placed in the cold-water bath for 10 min. and then immersed 5 sec. later in the hot-water bath left therein 10 min., and then removed and examined. The temperature of the water in the hot bath shall be between 150 and 170 F. (65 and 77 C.), and the temperature difference between the cold and the hot baths at the time of immersion shall be 100 ± 2 F. (56 ± 1 C.).

(*f*) *Observations.*—After each of the above thermal shock tests (Paragraphs (*d*) and (*e*)) the insulators shall be examined for presence or absence of cracking, chipping, and spalling.

(*g*) *Retest.*—If 10 per cent of any set of specimens fail to meet the thermal shock tests, a retest on double the number but not less than 10 specimens, shall be made. If more than 10 per cent of this retest fail, the entire lot from which the specimens were selected shall be discarded.



2"
7/8"
3/8"
1 7/16"
1/16" rad.
1 1/2"
5/8"
7/8" U.S.Std. thread- 9 threads per inch
1/8"
15/16"
Material: Cold Rolled Steel
1/16" rad.
2 1/8"
1 1/4"
6 1/8"
1 1/4" U.S.Std. thread 7 threads per inch, right hand
2 1/2"
1 1/4"
11/16" diam. at small end of taper
1/16" rad.
Taper 1/16" in diam. per inch in length
1 1/4"
3/32"
Material: Chromium-Vanadium Steel, Tensile Strength 125,000 to 135,000 psi.
3 25/32"
2 25/32"
3/32" rad.
45°
7/16"
1 3/8"
1/4"
7/8"
1/16" rad.
3/4"
1"
7/8" U.S.Std. thread 9 threads per inch
7/8"
4 threads per inch, right hand. Taper 1/16" in diam per inch in length.
3/32" rad.
1/4"
5/64"
11/64"
1/16" rad.
Taper 1/16" in diam. per inch in length
3/32"
17/64"
3/4"
1"
1/64"
11/16" diam
2 1/4"
5/64"
2 21/64"
Material: Cast Lead

FIG. 1.—Detail of Pin and Cap for Mechanical Strength Test.

Mechanical Strength

7. The insulators shall be mounted on a lead (containing not over 5 per cent

antimony) threaded steel pin (Fig. 1) of sufficient strength to prevent permanent deflection during the pull required to fail the insulator. The load shall be applied mechanically at right angles to the pin through a $\frac{3}{8}$-in. flexible 6 by 19 wire rope in the side groove of the insulator. The method of applying the load is shown in Fig. 2 ($\frac{7}{16}$ copper-weld shackles procurable from line hardware manufacturers may be substituted). The load shall be applied uniformly and the speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.050 in. per min. when the machine is running idle. The strength of the insulator shall be the total load at first visible crack or fracture of the glass.

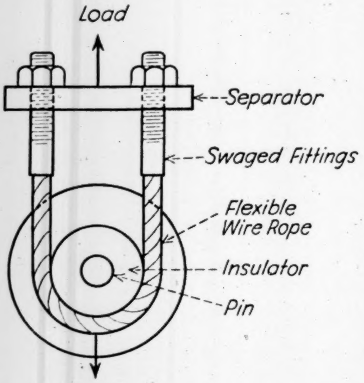


FIG. 2.—Shackle for Mechanical Strength Test of Glass Insulators.

ELECTRICAL TESTS

Electrical Flashover and Dielectric Strength

8. Electrical flashover and dielectric strength tests when applied shall be made in accordance with the tests for Pin Insulators as described in the American Institute of Electrical Engineers' Standard for Insulator Tests (A.I.E.E. No. 41, March, 1930) (American Standard C 29a –1930).

NOTE.—The applicable sections of the A.I.E.E. standard are given in Appendix II of these methods.

REPORT

Report

9. A report shall be made of tests made on each days production of insulators and shall include the following:

(*a*) A description of the material, the name and type, date of manufacture, and number of insulators in the days production.

(*b*) The number of insulators tested and the results of each of the routine tests, including:

(*1*) The minimum number of turns to release the gage, and limits of clearance in inches between the top end of the gage and the crown of the insulator,

(*2*) The hot to cold and cold to hot thermal shock sustained, and,

(*3*) The minimum and average value of the mechanical strength tests in pounds.

Record

10. The results obtained shall be preserved as a record.

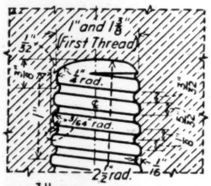
Marking

11. Insulators inspected and tested during production in accordance with these methods of test may be so designated by imprinting on the container the date of manufacture, and the statement that they were tested in accordance with A.S.T.M. Methods D 468 – 38 T, together with a reference to the test report by number.

APPENDIX I

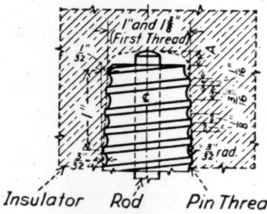
INSULATOR THREADS AND GAGES

This appendix is incorporated as a guide in guarding against the common contingency of misunderstanding by the use of improper gages occasioned by the fact that pin formations for insulators used by the power industry are different from the pin formations for insulators used by the telephone and telegraph industry. The insulator gages and thread formations shown in Fig. 3 are those adopted as standard for the power industry by the Edison Electric Institute and form part of its standard entitled "Suggested Specifications for Insulators and Pin Threads and Gages," approved by the Transmission and Distribution Committee, Edison Electric Institute (TD-71, 1937).


1" and $1\frac{3}{8}$" (First Thread)
$\frac{1}{32}$"
$\frac{1}{4}$" rad.
$\frac{3}{64}$" rad.
$2\frac{1}{2}$ rad.
$\frac{1}{16}$"
℄

1" and $1\frac{3}{8}$" Thread in Insulator

Note: Thread fit to be checked with insulator gage


1" and $1\frac{3}{8}$" (First Thread)
$\frac{1}{32}$"
A
$\frac{3}{32}$"
$\frac{3}{32}$" rad.
℄
Insulator
Rod
Pin Thread

1" and $1\frac{3}{8}$" Insulator Gage Thread

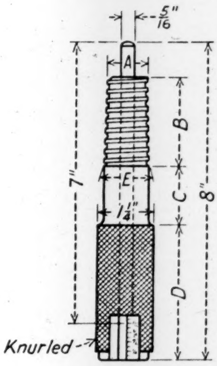
Notes: 1. *Allowable variation on all dimensions..... ±0.5 per cent*

2. *Allowable clearance at "A"... $\frac{1}{4}$" to $\frac{5}{8}$"*

3. *Number of turns necessary to release gage... 3 turns, min.*

All Threads

4 threads per inch, tapering $\frac{1}{16}$" in diameter to 1" in length


$\frac{5}{16}$"
A
B
C
D
E
$1\frac{1}{4}$"
7"
8"
Knurled

1" and $1\frac{3}{8}$" Insulator Gages

Notes: 1. *Insulator gages shall be used to gage threads in insulators as specified in the specifications*

2. *Threads shall be accurate dimension finish, dry cut and polished after hardening*

3. *Allowable variation of ±0.5 per cent on all dimensions*

4.

	A	B	C	D	E
1" Gage....	1"	$2\frac{1}{4}$"	$1\frac{1}{2}$"	$3\frac{3}{8}$"	$1\frac{9}{64}$"
$1\frac{3}{8}$" Gage....	$1\frac{3}{8}$"	3"	$\frac{1}{2}$"	$3\frac{5}{8}$"	$1\frac{9}{16}$"

5. *Material: Tool steel*

6. *Finish: Smooth except as noted*

FIG. 3.—Insulator Threads and Gages.

APPENDIX II

ELECTRICAL FLASHOVER AND DIELECTRIC STRENGTH TESTS

The following descriptions of the tests for electrical flashover and dielectric strength have been taken from the American Institute of Electrical Engineers' Standard for Insulator Tests (A.I.E.E. No. 41, March, 1930) (American Standard C 29a-1930), Paragraphs 41-100, 41-101, 41-103, 41-104, 41-202, 41-203, 41-600 and 41-601. Sections A6 and A7 appear in the A.I.E.E. standard as Paragraphs 41-600 and 41-601 in an appendix entitled "for information only."

A1. *Dry Flashover Test.*[1]—Dry flashover test shall be performed with the pin insulator mounted in a vertical position on a steel pin of circular section 1 in. (2.54 cm.) in diameter mounted on a cross-arm, and of such length that the ratio of the shortest distance from the outer edge of the head, around the insulator to the cross-arm, to the shortest distance from the edge of the head around the insulator to the pin shall be 1.25. The cross-arm shall be a grounded metallic tube not less than 3 in. (7.63 cm.) and not more than 5 in. (12.7 cm.) in outside diameter and shall extend at least 3 ft. (0.914 m.) on either side of the center line of the insulator pin. No other grounded structure shall be nearer than 3 ft. (0.914 m.) to any part of the insulator or conductor. The head of the insulator shall be fitted with a straight smooth metallic rod or tube not less than 0.5 in. (1.27 cm.) in outside diameter extending in a direction at right angles to the cross-arm and at least 2 ft. (0.609 m.) in either direction from the center line of the insulator head. This rod shall be secured in the upper groove by means of at least one turn of wire not smaller than No. 8 A.w.g. placed in the side tie wire groove, the ends being closely wrapped about the rod on each side of the insulator out to a point vertically above the edge of the largest petticoat.

The test shall be performed by applying voltage between the rod fastened to the head and the steel pin, and raising it at a rate of approximately 10,000 v. every 15 sec. to a value at which dry flashover occurs. The initial applied voltage may be raised quickly to approximately 80 per cent of dry flashover voltage.

Flashover voltage shall be determined at or corrected to a standard humidity corresponding to a vapor pressure of 0.6085 in. (15.45 mm.) of mercury. This is equivalent to a relative humidity of 65 per cent at 77 F. (25 C.) and a barometric pressure of 30.0 in. (76.2 cm.) of mercury. Humidity shall be measured with wet and dry bulb thermometers, the air being circulated past the thermometers at a velocity of 3 m. (9.84 ft.) or more per second or by the sling psychrometer. The measurements shall be reduced to vapor pressure with the assistance of the Smithsonian Meteorological Tables or by the following formula:

$$E = E' - 0.000367\,B\,(t - t')\left(1 + \frac{t' - 32}{1571}\right)$$

where E = vapor pressure in inches,
E' = pressure of saturated aqueous vapor at temperature t',
t = temperature of the air in Fahrenheit degrees,
t' = temperature of the wet-bulb thermometer in Fahrenheit degrees, and
B = barometric pressure in inches.

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[1] It is expected that the data obtained from these tests will permit development of a practicable laboratory procedure for correcting flashover tests for humidity. (See Paragraphs A6 and A7.)

A2. *Wet Flashover Test.*—Except that no provision need be made for controlling the temperature and relative humidity of the air, the testing arrangement shall be the same as in the dry flashover test with the addition of equipment to provide a finely divided and reasonably uniform spray at an angle of 45 deg. from the vertical and at a rate of precipitation of 0.2 in. (5.07 mm.) per min. The water shall have a resistance of from 6000 to 8000 ohms per inch cube (15,200 to 20,300 ohms per cm. cube) and shall be delivered to the spray nozzle at a pressure of not less than 35 and not more than 50 lb. per sq. in. (2.46 to 3.51 kg. per sq. cm.) measured at the nozzle. The vertical and horizontal dimensions of the vertical area sprayed shall be measured in a plane through the vertical axis of the insulator and shall be at least 1.75 times the corresponding over-all projected dimensions of the insulator. The precipitation shall be determined by measurements taken, with the insulator removed, at the location of the top, center and bottom of the vertical axis of the insulator when in its test position. The water shall be collected in a vessel having a top diameter of 6 in. (15.24 cm.). Individual measurements shall show a variation of not more than 25 per cent from the mean of the three measurements.

This standard spray shall be applied to the insulator for 1 min. prior to the test and during the test. Before applying the standard spray, the insulator shall be given a thorough preliminary wetting either by immersion, by spraying in an inverted position or by using a hose on the insulator in its test position.

The test shall be performed by applying voltage between the rod fastened to the head and the steel pin, and raising it at a rate of approximately 10,000 v. every 15 sec. to a value at which wet flashover occurs. The initial applied voltage may be raised quickly to approximately 80 per cent of the wet flashover voltage.

A3. *Flashover Tolerances.*[1]—The flashover voltages of a pin-insulator design shall be considered as checked, if the average of the dry flashover voltages of three insulators shall be within 5 per cent and the average of the wet flashover voltages of three insulators shall be within 10 per cent of the corresponding assigned voltage.

A4. (*a*) *Puncture Test.*—Puncture test shall be performed with the insulator inverted and so immersed in insulating oil that the oil will be at least 6 in. (15.24 cm.) deep over all parts of the insulator. The insulating oil shall be capable of withstanding 15 kv. between 1 in. (2.54 cm.) disks spaced 0.1 in. (0.254 cm.) apart. The head of the insulator shall be covered with a cap of conducting cement approximately 1 in. (2.54 cm.) thick and 0.75 in. (1.90 cm.) larger in radius than the insulator head. The pin hole shall be provided with a cemented thimble in which shall be inserted a close fitting metal pin. Oil[2] may be excluded from the space between the pin and the thimble by means of cement.

The test shall be performed by applying voltage between the cement cap and the steel pin, and raising it at a rate of approximately 10,000 v. every 15 sec. to a value at which puncture occurs. The initial applied voltage may be raised quickly to the dry flashover voltage.

(*b*) Puncture test shall be made on insulators which have passed the routine flashover tests. Rejection of insulators for puncture shall be based on the "Per Cent Average Variation" in puncture voltage determined as described in Paragraph A5.

A5. *Determination of "Per Cent Average Variation" in Puncture Test.*—Purchaser will select from the insulators offered for final inspection not more than one-half of one per cent of the total quantity and not less than three insulators.

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[1] These flashover tolerances are made to provide for testing variables which are difficult to control.

[2] The procedure for testing oil is completely described in the Standard Methods of Testing Electrica Insulating Oils (A.S.T.M. Designation: D 117) of the American Society for Testing Materials, 1936 Book of A.S.T.M. Standards, Part II, p. 1167.

Let

$V_1\ V_2\ V_3\ .\ .\ .\ .\ V_n$ = individual puncture values

V = average puncture voltage

$V = (V_1 + V_2 + V_3\ .\ .\ .\ .\ + V_n)/n$

Let

$a_1 = V - V_1 \qquad a_2 = V - V_2$

$a_3 = V - V_3 \qquad a_n = V - V_n$

Consider all the values of a as positive, that is, neglect the signs.

Let

a = average variation

A = per cent average variation

Then

$a = (a_1 + a_2 + a_3\ .\ .\ .\ .\ + a_n)/n$

$A = 100\,a/V$[*]

If "Per Cent Average Variation," A, exceeds 10 per cent, the entire quantity shall be rejected, or at the manufacturer's option and expense an additional 2 per cent or a minimum of 10 insulators may be tested. In this case the results of the second test alone shall be considered and if the "Per Cent Average Variation," A, exceeds 10 per cent the entire quantity represented shall be rejected. Further if the average puncture voltage V is less than 133⅓ per cent of rated dry flashover voltage, the entire quantity represented shall be rejected.

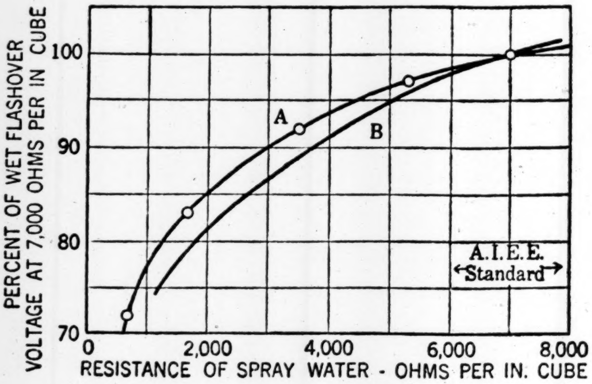

FIG. 4.

A6. *Variation of Wet Flashover Voltage with Water Resistance.*—It is frequently difficult to get consistent results for wet flashover voltages of insulators when the tests are made in different laboratories. This is sometimes largely due to the difference in resistance of the spray water. Tap water is sometimes 2000 ohms per inch cube or less, and steam condensate is sometimes over 50,000 ohms. In the Standards it is stated that the water shall have a resistance of from 6000 to 8000 ohms per inch cube, so that it always should be possible to obtain spray water of the specified resistance by treatment of the condensate or by mixing condensate with tap water.

The effect of using low-resistance water is well shown by the two curves given in Fig. 4, which are from independent sources. Curve A was contributed by Mr.

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[*] ***Example.*—Five insulators punctured at: 150, 135, 145, 138, 142 kv., respectively:**

$V = (150 + 135 + 145 + 138 + 142)/5 = 142$

$a = (8 + 7 + 3 + 4 + 0)/5 = 4.4$

$A = 100 \times 4.4/142 = 3.09$ per cent

F. W. Peek, Jr., and Curve *B* was adapted from a discussion of the German Standards appearing in *Elektrotechnische Zeitschrift*. Mr. Peek's curve is based on tests of three, five and eight-unit suspension strings of 10-in. disks. The German curve is described as applying to "Cap type, insulators, flat shape; small suspension insulators; disk type strain insulators with metal skirt." In each case, 100 per cent flashover voltage is taken as the flashover voltage with water of 7000 ohms per in. cube resistance, this being half-way between the extremes permitted by the Standards.

A7. *Method of Reducing Dry Flashover Tests to Standard Humidity.*—For reducing dry flashover test voltages determined under conditions of humidity different from standard to standard humidity conditions the following method will be acceptable although it is expected that experience will result in the development of a simpler method.

Flashover voltages for a particular insulator design may be measured at three different humidities, at least one test being made at a humidity higher than standard and at least one test being made at a humidity lower than standard. The flashover voltage for standard humidity shall then be determined by graphical interpolation along a smooth curve drawn through the three points determined by plotting the test results with flashover voltage and vapor pressure as coordinates.

For the purpose of controlling humidity, a pin-type insulator and its support may be placed within an inclosure not less than 10 ft. (3.05 m.) cube. In the case of suspension insulators, the insulator or string and its support may be placed within an inclosure not less than three times the string length in any dimension, and in no case less than 10 ft. (3.05 m.) cube.

Insulators under test shall be at approximately the same temperature as the surrounding air.

TENTATIVE METHODS OF TESTING SHEET AND PLATE MATERIALS USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 229 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1925; REVISED, 1926, 1928, 1930, 1931, 1932, 1934, 1935, 1936, 1937, 1938.[2]

Scope

1. These methods are intended to apply to stiff, flat sheet and plate materials, such as phenolic and other types of laminated sheets, vulcanized fiber, hard rubber, asbestos composition board, etc., to be used as electrical insulation.

Definition of Terms

2. In referring to the cutting of the specimens and the application of the load, the following definitions apply:

Flatwise.—Load applied to the flat side of the original sheet or plate.

Edgewise.—Load applied to the edge of the original sheet or plate.

Lengthwise.—In the direction of the length of the sheet.

Crosswise.—In the direction at right angles to the length of the sheet.

NOTE.—When the sheet has the same length and width, one dimension shall arbitrarily be designated as the length, and the other as the width.

THICKNESS

Thickness Measurements

3. (*a*) *On Test Specimens.*—In the test methods which follow, all thickness measurements shall be made using a machinist's micrometer in the manner outlined under Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 - 36 T) of the American Society for Testing Materials.[3]

(*b*) *On Large Sheets.*—In the factory, measurements of large sheets of material may be made by using a gage mounted on a yoke of sufficient size and rigidity to permit accurate measurements in the center of the sheet.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] Latest revision accepted by Committee E-10 on Standards, August 25, 1938.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1026 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1196.

NOTE.—Results of comparative tests in several factories, measuring 36-in. square sheets by a variety of such devices, indicate that the trade is able to measure sheets $\frac{1}{32}$ and $\frac{1}{8}$ in. in thickness to an accuracy of 0.0015 in. (In the tests, σ, or root mean square deviations, of 0.0005 were obtained.)

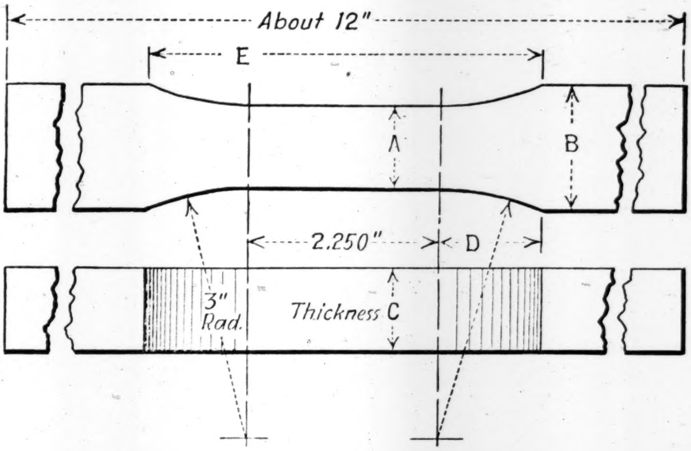
TENSILE STRENGTH

Apparatus

4. Any standard type of testing machine may be used. The machine shall be accurate to within 1 per cent on the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned.

Specimens

5. Tension test specimens shall conform to the dimensions shown in Fig. 1. The surfaces of the specimen shall be smooth and free from scratches.



When C is less than $\frac{1}{8}$ in., A is $\frac{1}{2}$ in., B is $\frac{3}{4}$ in., D is 0.857", E is 3.964 in.
When C is $\frac{1}{8}$ in. or over, A is 1 in., B is $1\frac{1}{2}$ in., D is 1.199", E is 4.648 in.

FIG. 1.—Tension Test Specimen for Laminated Sheet Insulating Materials.

Procedure

6. Five specimens cut lengthwise and five specimens cut crosswise of the sheet shall be tested.

Temperature

7. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine

8. The cross-head speed of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.05 in. per minute when the machine is running idle.

Elongation Under Load

9. When it is desired to determine the elongation under load, a suitable extensometer measuring the elongation on a 2-in. gage length shall be used. The cross-head speed of the testing machine shall not exceed 0.03 in. per minute when the machine is running idle.

Procedure

10. The total change in length between zero load and a stress of 5000 lb. per sq. in. shall be determined.

Report

11. The report shall include the following:

(*a*) The direction in which the specimen was taken, whether lengthwise or crosswise of the sheet.

(*b*) The thickness and width of each specimen in inches expressed to the nearest 0.001 in. or in centimeters expressed to the nearest 0.025 mm.

(*c*) The breaking load of each specimen, in pounds or kilograms.

(*d*) The tensile strength of each specimen, in pounds per square inch or in kilograms per square centimeter.

(*e*) The location and nature of the fracture.

(*f*) The elongation in inches at a stress of 5000 lb. per sq. in., if determined.

(*g*) The room temperature.

FLEXURAL STRENGTH

(FORMERLY CALLED TRANSVERSE STRENGTH)

(*A*) *For Materials $\frac{1}{32}$ in. or Over in Thickness*[1]

Apparatus

12. (*a*) Any standard type of testing machine may be used. The machine shall have an accuracy of at least 1 per cent of the lowest load for which it is used.

(*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. for material $\frac{1}{8}$ in. or over in thickness, and to a radius of $\frac{1}{16}$ in. for thinner materials. For material thinner than $\frac{1}{8}$ in. both supports shall be provided with a pin or other stop to align one side of the specimen perpendicular to the line of contact with the supports. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction, except that the minimum span shall be ½ in.

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[1] Conventional flexure tests in a flatwise direction are not recommended for materials thinner than $\frac{1}{32}$ in. nor in the edgewise direction for materials thinner than $\frac{1}{4}$ in.

Specimen

13. The test specimen shall be ½ in. in width except for specimens over ½ in. in thickness tested in the flatwise direction, which shall have the width equal to the thickness of the specimen. The thickness shall be the full thickness of the sheet. The length shall be 1 in. greater than the distance between the points of support as specified in Section 12 (*b*).

Procedure

14. The specimens shall be tested as follows:

(*a*) Five specimens cut lengthwise of sheet, tested flatwise.

(*b*) Five specimens cut lengthwise of sheet, tested edgewise.

(*c*) Five specimens cut crosswise of sheet, tested flatwise.

(*d*) Five specimens cut crosswise of sheet, tested edgewise.

Temperature of Tests

15. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine

16. The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but shall not exceed 0.05 in. per minute when the machine is running idle.

Report

17. The report shall include the following:

(*a*) The directions of cutting and loading of the specimen as specified in Section 14.

(*b*) The thickness and width of each specimen in inches expressed to the nearest 0.001 in. or in centimeters expressed to the nearest 0.025 mm.

(*c*) The breaking load of each specimen in pounds or kilograms.

(*d*) The maximum fiber stress in pounds per square inch or kilograms per square centimeter calculated from the formula:

$$S = \frac{3}{2} \frac{Pl}{bd^2}$$

where S = maximum fiber stress;

P = breaking load in pounds or kilograms;

l = distance between supports in inches or centimeters;

b = width of specimen in inches or centimeters;

d = depth of specimen in inches or centimeters.

(*e*) The room temperature.

COMPRESSIVE STRENGTH

Apparatus

18. Any standard testing machine may be used provided it is accurate within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable, at the top, and the metal bearing plates shall be directly in contact with the ends of the test specimen.

Specimen

19. (*a*) For sheets 1 in. in thickness or over, the test specimen shall be a 1-in. cube, the faces of which shall be flat and perpendicular to the axes, being ground to this condition if necessary.

(*b*) For sheets less than 1 in. in thickness, the specimen shall consist of a pile of sheets 1 in. square with a minimum number of layers to produce a height of at least 1 in.

Procedure

20. (*a*) For sheets 1 in. in thickness or over, three specimens shall be crushed in the condition in which they are received with the load applied flatwise, three specimens with the load applied edgewise-lengthwise of the sheet and three specimens with the load applied edgewise-crosswise of the sheet.

(*b*) For sheets less than 1 in. in thickness, three specimens shall be crushed in the condition in which they are received with the load applied flatwise of the sheet.

21. The load shall be applied on the ends of the specimen and the crosshead speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.050 in. (1.27 mm.) per minute when the machine is running idle. For the best results use the slowest possible speed.

Report

22. The report shall include the following:

(*a*) The dimensions of each specimen in inches expressed to the nearest 0.001 in. or in centimeters expressed to the nearest 0.025 mm.

(*b*) The direction of application of the load;

(*c*) The load on each specimen in pounds or kilograms at the first sign of failure;

(*d*) The ultimate compressive strength in pounds per square inch or kilograms per square millimeter, of each specimen, calculated from the area of each specimen measured before the load is applied;

(*e*) The general character of the material tested; with a description of how it acts under the applied load.

RESISTANCE TO IMPACT

Impact Test

23. (*a*) Resistance to impact shall be determined in accordance with the Standard Methods of Test for Impact Resistance of Electrical Insulating Materials (A.S.T.M. Designation: D 256) of the American Society for Testing Materials.[1]

(*b*) Specimens for the Charpy test may be notched or unnotched, as desired, according to conditions of service, and for the Izod test shall be notched (Note 1). Specimens shall be cut both lengthwise and crosswise of the sheet (Note 2).

NOTE. 1.—The unnotched specimen gives a higher strength than the notched specimen and the ratio of the strength of the unnotched specimen to that of the notched specimen varies with different materials.

NOTE 2.—Conditioning of the specimens of vulcanized fiber is necessary in order to secure consistent results. The procedure for conditioning is under consideration by the committee. In order to secure comparative results, the specimens should be conditioned at the same temperature and humidity.

WATER ABSORPTION TESTS

Scope

24. The water absorption tests are intended to determine the rate at which water is absorbed by the material when immersed, the total quantity absorbed at saturation, and the volatile content as received.

NOTE.—The electrical properties of different materials are not necessarily affected to the same extent by the same increase in moisture content so that the water absorption test must be correlated with the desired electrical tests.

The water immersion test and exposure to air of high humidity are not always directly comparable and should be considered before substituting one for the other.

(*A*) *Rate of Absorption*

Specimen

25. The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches to the nearest 0.001 in. shall be measured on the original specimen at the center.

Procedure

26. To determine the rate of absorption, two specimens shall be tested individually as follows:

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 169.

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately re-weighed. The difference between the original weight and the dry weight shall be recorded as loss in weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water maintained at a temperature of 25° C. ± 2° C. (77° F. ± 3.6° F.) throughout the test. At the end of 2 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. If the specimen is $\frac{1}{16}$ in. in thickness or less it shall be weighed in a weighing bottle. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen.

(*c*) After 24 hours immersion the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24 hours immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen. If the individual 24-hour absorptions differ by more than 10 per cent from the average absorption of the two specimens the test shall be repeated.

Report

27. The report shall include the values for each of the two specimens and the average values as follows:

(*a*) The thickness of the specimen before the test, to the nearest 0.001 in.;

(*b*) The percentage loss in weight on drying calculated on the original weight;

(*c*) The percentage of water absorbed in 2 hours and in 24 hours calculated on the dry weight.

(*B*) *Total Absorption at Saturation*

Specimen

28. The test specimen shall be 3 by 1 in. by the thickness of the material for materials $\frac{1}{8}$ in. in thickness or less. For materials over $\frac{1}{8}$ in. in thickness the specimen shall be 3 by $\frac{1}{8}$ in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test speci-

mens shall be finished with No. 0 or finer sandpaper or emery cloth. The sawing and sandpapering operations should be slow enough so that the material is not heated unnecessarily. The thickness in inches measured to the nearest 0.001 in. shall be measured in the direction perpendicular to the faces of the original sample.

Procedure

29. To determine the total water absorption at saturation, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately reweighed. The difference between the original weight and the dry weight shall be recorded as loss of weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water at a temperature of from 20 to 30° C. At the end of 24 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. The weighings shall be repeated every day for the first week and every week thereafter until the increase in weight, as shown by three consecutive weighings, averages less than 1 per cent of the total increase in weight, when the specimen shall be considered to be saturated.

(*c*) The difference between the saturated weight and that of the dry weight shall be considered as the water absorbed at saturation. The percentage of water absorbed shall be calculated on the dry weight of the specimen.

Report

30. This report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of material, measured to the nearest 0.001 in.;

(*b*) The percentage loss in weight on drying, calculated on the original weight;

(*c*) The percentage of water absorbed at saturation, calculated on the dry weight.

(*C*) *Volatile Matter*

Specimen

31. The test specimen shall conform to that used for the total absorption test, and shall meet the requirements specified in Section 28.

Procedure

32. To determine the volatile matter, two specimens shall be tested individually as follows:

The specimen shall be weighed, dried in an oven at from 105 to 110° C. until the decrease in weight as shown by two consecutive weighings at least 24 hours apart is less than 1 per cent of the total decrease in weight. The difference between the original weight and the dry weight shall be recorded as the volatile matter present in the specimen as received (this includes in addition to water any volatile solvent left during manufacture). The percentage of volatile matter shall be based on the weight of the dry specimen.

Report

33. The report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of the material measured to the nearest 0.001 in.;

(*b*) The percentage of volatile matter, based on the weight of the dry specimen.

DIELECTRIC STRENGTH

Dielectric Strength

34. (*a*) Except as specified below in Sections 35 to 39, the dielectric strength shall be determined in accordance with the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 - 38 T) of the American Society for Testing Materials.[1]

(*b*) Tests shall be made transverse or parallel to the flat sides, or both, depending upon whether the stress on the material when in use is to be transverse or parallel to the flat sides, or both.

Electrodes and Test Specimens

35. (*a*) Transverse tests shall be made between the standard 2-in. electrodes.

NOTE.—Surface creepage and flashover at the higher voltages may be prevented by pouring around the electrodes any high-grade insulating compound which will form a good bond with the material and with the electrodes. Sealing wax and phenolic resin varnish have been successfully used under certain conditions. In applying this protective compound, care shall be taken to prevent voids under the edges of the electrodes.

(*b*) For tests parallel to the flat sides, the material shall be cut into sections 2-in. square. Holes shall be drilled into opposite edges of each section so as to line up with each other, the inner ends of the holes being ½ in. apart. Metal electrodes shall be used, the ends of which exactly fit the ends of the holes. Thus, in effect, the material is tested edgewise in a modified needle gap. The diameter of the hole should be approximately one-fourth the thickness of the specimen. For very thin specimens it may be necessary to use a larger ratio of drill size. Results shall be expressed in total kilovolts breakdown.

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[1] See p. 1001.

Conditioning

36. (*a*) In the case of materials known to be affected by humidity, conditioning prior to dielectric strength test shall be carried out in accordance with the material specification applying to the material to be tested.

(*b*) Where the materials are to be used at other than room temperature, their dielectric strength characteristic shall be determined over the operating range of temperature. Prior to test, specimens shall be exposed to each test temperature in a suitable temperature-control chamber for a period in minutes equal to half the thickness of the specimen in mils.

Surrounding Medium

37. All tests shall be made under oil, maintained at the same temperature as the test specimen.

Procedure

38. (*a*) Tests shall be made by either the short-time method or the step-by-step method.

(*b*) In the short-time test, voltage shall be increased at the rate of 0.5 kv. per sec.

(*c*) In the step-by-step test, the voltage shall be increased in increments as indicated in the following table, the voltage being held at each step for 1 min.:

BREAKDOWN VOLTAGE BY SHORT-TIME METHOD	INCREMENT OF INCREASE OF TEST VOLTAGE
25 kv. or less	1.0 kv.
Over 25 to 50 kv., incl	2.0 kv.
Over 50 to 100 kv., incl	5.0 kv.
Over 100 kv	10.0 kv.

Number of Tests

39. At least five tests shall be made at each test temperature in the short-time method, and at least three tests in the step-by-step method. Where the range of test temperature is considerable, tests should be made at not less than four temperatures, so that a curve of dielectric strength against temperature may be plotted.

PHASE DIFFERENCE (POWER FACTOR) AND DIELECTRIC CONSTANT

Dielectric Constant

40. The phase difference and dielectric constant shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 – 36 T) of the American Society for Testing Materials.[1]

BONDING STRENGTH

For Laminated Materials $\frac{3}{16}$ in. or Over in Thickness

Apparatus

41. Any standard type of testing machine may be used, providing it is accurate within 1 per cent of the lowest load for which it is used. To this shall be fitted a head containing a 10-mm. steel ball.

Specimens

42. Test specimens shall be 1 in. square, smoothly and accurately cut on a smooth saw.

Procedure

43. Five specimens shall be tested. These shall be placed on edge and the steel ball shall center accurately between the edges and ends of the specimen.

Temperature

44. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine

45. The speed of the cross-head of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.05 in. per minute when the machine is running idle.

Report

46. The report shall include the following.

(*a*) the thickness of the material; and

(*b*) the load, expressed in pounds or kilograms, required to split the specimen.

ROCKWELL HARDNESS

Apparatus

47. (*a*) The Rockwell hardness tester shall be used, conforming to the requirements of the Standard Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18) of the American Society for Testing Materials.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 955 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1071.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 824.

(*b*) The readings shall be taken on the red scale and shall be recorded as follows: Count the number of times the needle passes through zero on the red scale on the application of the major load. Subtract from this the number of times the needle passes through zero upon the removal of this load. If the difference is zero, the reading shall be recorded as over 100. If the difference is 1, the reading shall be recorded as between 0 and 100 and, if the difference is 2, the reading shall be recorded as negative.

Specimen

48. (*a*) The specimen shall have a minimum thickness of $\frac{1}{4}$ in. The specimen may be composed of a pile-up of several pieces of the material of the same thickness, providing that precaution is taken that the surfaces of the pieces are in contact and not held apart by burrs from saw cuts, etc. The area of the specimen shall be 1 in. square if cut from sheet stock or other shape of at least this area.

(*b*) Care shall be taken that the test is not made so near the edge of the specimen that it will break out when the major load is applied.

(*c*) The specimen shall be supported in such a manner as to prevent errors due to overhang, when it does not balance itself on the anvil.

(*d*) All tests shall be made at a temperature of 25 C. ± 2 C. (77 F. ± 3.6 F.).

NOTE 1.—It should be noted that some materials such as laminated phenolic plates show an appreciable variation in the Rockwell hardness with variation in temperature as small as 8° C. (15° F.).

NOTE 2.—Conditioning of the specimens of vulcanized fiber is necessary in order to secure consistent results. The procedure for conditioning is under consideration by the committee. In order to secure comparative results, the specimens should be conditioned at the same temperature and humidity.

Procedure

49. (*a*) The procedure outlined in the Standard Methods E 18[1] shall be followed. The adjustment of speed of load application and the time of application of the major load are of great importance. The machine shall be so adjusted that the major load will be fully applied in from 6 to 8 seconds as a longer time will give an erroneous result due to "creeping" of some materials. It is important that the major load be removed within 1 sec. after the crank handle mechanism has come to a stop.

(*b*) For phenolic laminated sheets, a $\frac{1}{4}$-in. ball penetrator, a minor load of 10 kg. and a major load of 100 kg. shall be used in connection with the red scale. This combination is known as the M scale.

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[1] 1936 Book of A.S.T.M. Standards, Part I, p. 824.

(*c*) For vulcanized fiber, a $\frac{1}{2}$-in. ball penetrator, a minor load of 10 kg. and a major load of 60 kg. shall be used. This combination is known as the R scale. The major load shall be removed within seven to eight seconds after the handle has been tripped. Care shall be taken that the weight arm does not descend far enough to rest on the lifting link or pin. If the arm rests on the link or pin, the load or penetrator should be changed.

Report

50. The report shall include the following:

(*a*) The Rockwell hardness number read on the red scale, the major load and the diameter of the penetrator. The letter M shall precede the Rockwell hardness number for phenolic laminated sheets and the letter R shall precede that for vulcanized fiber.

(*b*) The total thickness of the specimen;

(*c*) The number of pieces in a specimen and their average thickness, and

(*d*) The room temperature.

DENSITY (VULCANIZED FIBER)

Density

51. (*a*) *Fiber 0.020 in. or less in Thickness.*—For vulcanized fiber 0.020 in. or less in thickness the specimen shall be dried in an oven for 2 hr. at 105 to 110 C. It shall then be weighed on a chemical balance accurate to 0.25 per cent. The thickness shall be determined after drying. The apparent density shall be calculated from the thickness and the weight by means of the following formula:

$$\begin{array}{c}\text{Apparent Density,}\\ \text{g. per cu. cm.}\end{array} = \frac{\text{Weight in grams}}{\text{Volume in cu. in.}} \times 0.061$$

(*b*) *Fiber over 0.020 in. in Thickness.*—The density of vulcanized fiber over 0.020 in. in thickness shall be determined with any suitable weight-difference apparatus for making readings in water and air using the specimen as received.

ASH (VULCANIZED FIBER)

Specimen

52. The test specimen shall consist of 2 to 5 g. of finely divided particles, such as millings or filings, of the vulcanized fiber.

Procedure

53. The test specimen shall be dried for 2 hr. at 105 to 110 C., weighed, then ignited to constant weight in a crucible and weighed. The percentage of ash shall be calculated, based on the weight of the dried specimen.

ZINC CHLORIDE (VULCANIZED FIBER)

Specimen

54. The test specimen shall consist of 5 g. of finely divided particles, such as millings or filings, of the vulcanized fiber.

Procedure

55. (*a*) The test specimen shall be dried for 2 hr. at 105 to 110 C.

(*b*) The dried specimen shall be placed in a Soxhlet, Wiley-Richardson, or similar type of extractor and extracted with distilled water for 3 hr. The rate of extraction with the Wiley-Richardson size of extractor must be sufficient to cause the tube containing the sample to be filled by condensation and emptied by the siphon at least six times per hour. When the Soxhlet or similar size extractor is used the tube must be filled and emptied at a rate of at least 3 cycles per hour. After this extract has cooled, 0.5 ml. of potassium chromate solution (10 per cent) shall be added and the extract titrated with standard silver nitrate solution. The end point is indicated by the appearance of a permanent red color. A blank test shall be made on an equal volume of distilled water and potassium chromate solution and the result shall be subtracted from that of the specimen. The net result shall be calculated in terms of zinc chloride.

SILICA (VULCANIZED FIBER)

Specimen

56. The test specimen shall consist of 5 g. of finely divided particles such as millings or filings, of the vulcanized fiber.

Procedure

57. (*a*) The test specimen shall be dried for 2 hr. at 105 to 110 C.

(*b*) The dried specimen shall be transferred to a crucible and slowly ignited to constant weight. The ash shall be wet with distilled water and transferred to a heat-resistant glass beaker. About 75 ml. of HCl (sp. gr. 1.19) shall be added and the beaker covered with a watch glass. The contents of the beaker shall be evaporated to dryness. To the residue shall be slowly added 10 ml. of HCl (sp. gr. 1.19) followed by 75 ml. of distilled water. The mixture shall be filtered through ashless filter paper and washed with cold water, then with warm water until the filtrate is free from chlorides. The filter paper shall be ignited to constant weight in a weighed platinum crucible. Then, 4 ml. of HF (48 to 60 per cent) shall be added and heat applied until all white fumes are driven off. The crucible shall be cooled and weighed. The difference between this weight and the previous one indicates silicon present as silica. The results shall be expressed as a percentage of the weight of the dried specimen.

FLAMMABILITY

Scope

58. This test is intended to evaluate the tendency of the material to burst into flame under the continuous application of heat.

Apparatus

59. The apparatus shall consist of the following:

(*a*) *Shielding Box.*—A shielding box, made either of metal or wood, in which the test is conducted for the purpose of warding off air currents. This box shall be 12 by 24 in. by 16 in. in height and shall contain no front or top.

(*b*) *Resistance Wire.*—Seven feet of No. 30 B. & S. gage nichrome wire having a resistance of 6.75 ohms per foot ±5 per cent.

(*c*) An electrical connection for alternating or direct current of 110 v. Where necessary, the voltage may be brought to this value with a rheostat.

(*d*) A stop watch, voltmeter, and stand clamp.

Specimen

60. (*a*) The test specimen shall be smooth-sawed from sheets to dimensions of $\frac{1}{8}$ in. ±0.005 in. by 1 in. ±0.005 in. by 8 in. The edges of the specimen shall be notched by a milling machine. The notches shall be rectangular, $\frac{1}{32}$ in. in depth and 0.015 in. in width, and shall be spaced 10 notches to the inch. Binding posts shall be fastened at each end of the specimen. The resistance wire shall be wound firmly about the specimen into the notches, and the ends shall be fastened to the binding posts.

(*b*) The test specimens shall be conditioned for 24 hr. at 105 C. before test.

(*c*) Five specimens shall be tested.

Procedure

61. The shielding box shall be placed within a hood. The specimens shall be mounted on the stand clamp in a horizontal position with the laminations in a vertical position inside the box. The front of the hood shall be lowered to within 2 in. of the bottom. The starting switch shall be snapped on and at that instant the stop watch started. The current shall be adjusted to the specified voltage and when the sample bursts into flame the watch shall be stopped and the time interval from the beginning of the test shall be recorded.

Report

62. The report shall state the number of seconds required for the specimen to burst into flame.

TENTATIVE METHODS OF TESTING VARNISHED CLOTHS AND VARNISHED CLOTH TAPES USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 295 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1928; REVISED, 1929, 1932, 1933, 1934, 1936, 1937, 1938.

Scope

1. These methods are intended to apply to varnished cloths and varnished cloth tapes to be used as electrical insulation and are directly applicable to both the "straight-cut" and "bias-cut" materials, unless otherwise stated in the method.

SAMPLING

Selecting Rolls

2. (*a*) Shipments of varnished cloth and varnished cloth tapes shall be sampled as specified in Paragraphs (*b*) and (*c*). The rolls or pads shall be selected in such a manner as to be representative of the shipment.

(*b*) *Cloth.*—One roll shall be selected from each ten rolls in a shipment of full-width varnished cloth. The minimum number of rolls selected from any shipment shall be two.

(*c*) *Tape.*—At least one roll or pad shall be selected from each 1000 rolls or pads in a shipment of varnished cloth tape. The minimum number of rolls or pads selected from any shipment shall be ten.

Selecting Samples

3. (*a*) Except for tape shipped packed in oil, not less than two turns of cloth or six turns of tape from each roll or pad selected for sampling shall be torn off and discarded before the samples are selected. The number of samples required for purposes of test shall then be cut across the entire width of each roll or pad. The length of the samples shall not be less than 91.44 cm. (36 in.) for straight-cut material; from seam to seam for sewed bias-cut material; and from jointed-selvage to jointed-selvage for seamless bias-cut material.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

NOTE 1.—Specimens of bias-cut materials cut from the above samples shall exclude seams and jointed-selvages from the test areas.

NOTE 2.—If it is desired to test the seams or jointed-selvages for tensile breaking strength, additional specimens will have to be cut so that the seams or jointed-selvages are in the center of the specimens.

(*b*) From shipments such as sheets of cloth or strips of tape, the samples shall be representative of the shipment and shall be taken in accordance with Paragraph (*a*).

CONDITIONING

Conditioning

4. (*a*) The roll of cloth or tape from which specimens are to be cut shall be conditioned for a minimum of 2 hr. at a room temperature between the limits of 20 to 30 C., no humidity control.

(*b*) Specimens for tensile breaking strength, elongation, and dielectric strength "as received" shall be removed from the roll as required and tested immediately.

(*c*) If the room humidity is above 65 per cent, the roll of tape shall be kept in a cabinet whose relative humidity is maintained between 60 to 65 per cent.

(*d*) In the event of dispute, the test specimens shall be conditioned for 48 hr. at a temperature between 20 to 30 C. and at a relative humidity between 60 to 65 per cent.

THICKNESS

Apparatus

5. The thickness shall be measured in accordance with Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 – 36 T) of the American Society for Testing Materials.[1]

Specimens

6. Specimens for test shall consist of samples selected in accordance with Section 3.

Procedure

7. In making thickness measurements, only one layer of material shall be used.

Number of Measurements

8. (*a*) In the case of cloths, ten measurements equally spaced across the width of the specimen shall be taken and the thickness of the cloth shall be the average of the ten measurements.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1026 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1196.

(*b*) In the case of tapes, unless otherwise specified, ten measurements equally spaced along the length of each specimen shall be taken and the thickness of the tape shall be the average of the ten measurements.

NOTE.—The average thickness, as obtained in Section 15 for the dielectric strength test, may be conveniently used instead of the separate test described above.

Report

9. The report shall include the average, maximum, and minimum thicknesses in inches.

TENSILE BREAKING STRENGTH

Apparatus

10. (*a*) A testing machine[1] of the dead-weight pendulum type shall be used. The machine shall preferably be power driven.

(*b*) The capacity of the machine shall not exceed 113 kg. (250 lb.).

(*c*) The machine shall be graduated to read 1 lb. or 1 kg. or less per scale division for testing specimens breaking at 22.7 kg. (50 lb.) or over, and to 0.5 lb. or 0.5 kg. or less for testing specimens breaking under 22.7 kg. (50 lb.).

Test Specimens

11. Specimens cut from the full width cloth or from tapes over 2.54 cm. (1 in.) in width shall be 2.54 cm. (1 in.) in width and not less than 35.54 cm. (14 in.) in length. For tape having a nominal width of 2.54 cm. (1 in.) or under the specimens shall be of the original width and shall be not less than 35.54 cm. (14 in.) in length.

NOTE.—If it is desired to test the seams or jointed-selvages of bias-cut materials for tensile breaking strength, specimens obtained as described in Note 2 to Section 3 (*a*) shall be clamped in the testing machine so that the seams or jointed-selvages are midway between the two jaws. When testing, all readings obtained when the specimen breaks away from the seam or jointed-selvage shall be rejected.

Number of Specimens

12. (*a*) In the case of straight-cut cloths, ten specimens shall be cut in the direction of the warp threads and ten in the direction of the filling threads from samples selected in accordance with Section 3.

(*b*) In the case of bias-cut cloths, ten specimens shall be cut in the direction of the length from samples selected in accordance with Section 3.

(*c*) In the case of tapes, one specimen shall be cut from each roll selected in accordance with Section 2 (*c*).

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[1] This apparatus is the same as that used for the testing of paper and described in Section 16 of the Tentative Methods of Testing Untreated Paper Used in Electrical Insulation (A.S.T.M. Designation: D 202 – 38 T), see p. 1015.

Procedure

13. (*a*) The ratio of the clearance distance between jaws to the width of the specimen shall not be less than 5 to 1 nor more than 10 to 1.

(*b*) The rate of travel of the movable jaw shall be constant and preferably 30.5 cm. (12 in.) per minute, but it may be within the limits of 28 cm. (11 in.) and 33 cm. (13 in.) per minute provided it is constant.

(*c*) All readings obtained when the specimen breaks at or in the jaws shall be rejected.

Report

14. (*a*) The tensile breaking strength of a roll shall be the average of the breaking loads of all the specimens from the roll. The report shall include the average, maximum, and minimum breaking loads in kilograms or pounds together with the width of the specimens and the nominal thickness.

(*b*) In the case of straight-cut cloths, the tensile breaking strength of the warp threads and the filling threads shall be reported separately.

DIELECTRIC STRENGTH

(Short-Time and Step-by-Step Methods)

15. (*a*) Except as specified below in Sections 16 to 21, the dielectric strength shall be determined in accordance with the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 – 38 T) of the American Society for Testing Materials.[1]

(*b*) Dielectric strength tests may be applied to specimens of the material as-received, and on specimens from the elongation, resistance to oil, and humidity tests.

Apparatus

16. (*a*) For the testing of narrow specimens, such as tapes, it is necessary to use a special form of testing device, whereby the test specimen shall be clamped under pressure in order to prevent flashover around the edges of the material. Two forms of tester are described in the Appendix.

Test Specimens

17. (*a*) In the case of cloths, a specimen at least 10.16 cm. (4 in.) in width shall be cut diagonally from corner to corner from a sample selected in accordance with Section 3.

(*b*) In the case of tapes, the specimens shall be samples selected in accordance with Section 3.

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[1] See p. 1001.

Surrounding Medium

18. Tests shall be made in air unless the material is to be used under oil, in which case the material may be tested under oil.

Conditioning

19. Specimens shall be conditioned in accordance with Section 4.

Procedure

20. (*a*) Tests shall be made by either the short-time method or the step-by-step method, or by both methods.

(*b*) In the short-time method, voltage shall be increased at the rate of 0.5 kv. per sec.

(*c*) In tests made by the step-by-step method, each step shall be of 20-sec. duration. Voltage shall be increased by the following increments:

For tapes of 8 mils nominal thickness or less.................	250 v.
For tapes of over 8 mils nominal thickness...................	500 v.

The starting voltage shall be adjusted to the nearest even 250 or 500 v., depending on the increment of increase. The starting voltage should preferably be based upon the breakdown voltage in the short-time test, as provided in Tentative Methods D 149 – 38 T.[1] Where this may not be feasible or convenient, a starting voltage may be selected as the result of test experience, of such a value that at least three testing steps are obtained prior to breakdown.

Report

21. The report shall include the following:

(*a*) The method used for making the dielectric strength tests,

(*b*) The average dielectric strength in volts per mil and any other values of dielectric strength as required by the materials specifications, and

(*c*) The temperature at which the tests were made.

ENDURANCE DIELECTRIC STRENGTH TEST

Scope

22. This test is recommended for use where some idea of the relative dielectric strength of various materials when subjected to electrical stress for relatively long periods at high temperature is desired.

Test Specimens

23. (*a*) The specimens shall be made by wrapping the material, in tape form with one-quarter lap, one-half lap, butt-jointed or as sheets on brass tubes. The tubes shall be, for sheets and for tape

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[1] See p. 1001.

up to $1\frac{1}{2}$ in. in width, about 36 in. in length and 1 in. in outside diameter. For tapes wider than $1\frac{1}{2}$ in., the tubes shall be 2 in. in outside diameter. The sample shall be built up to the desired thickness, simulating practical conditions, winding all layers of tape in the same direction.

(*b*) A smooth layer of metal foil shall then be wrapped over the insulation for a distance of 24 in., leaving 6 in. of insulation uncovered at each end of the tube. The metal foil shall be bound in place with a wrapping of adhesive tape which shall extend the full length of the tube in order to protect the insulation at the end from corona discharge.

(*c*) A thermocouple shall be applied to the metal foil near the center of the tube and held in place by the adhesive tape.

Procedure

24. (*a*) The specimen shall be mounted in an oven and a temperature of 100 C. (212 F.) maintained during the test. Provision shall be made for so mounting the specimen that the tube may be connected to the high voltage side of the circuit with the metal foil sheath and thermocouple connected to ground.

(*b*) A voltage equal to 10 per cent of the breakdown voltage (to the nearest kilovolt) obtained in the short-time test shall be applied and maintained for 30 min. The voltage shall then be increased by steps of 20 per cent of the initial value until puncture occurs, the voltage being held at each step for 30 min.

(*c*) The temperature of the sample as indicated by the thermocouple shall be observed at intervals during the test and recorded at the end of each 30-min. period. It will be found that the temperature rises gradually until just before breakdown when the temperature increases rapidly. During this latter period, temperature readings shall be recorded at frequent intervals.

Report

25. The results shall be plotted using time, expressed in hours, as abscissas, and temperature, in degrees Centigrade, as ordinates. In addition to time as abscissas, the values of applied kilovolts shall be indicated since the value of kilovolts increases uniformly with time. The significant values to be taken from the curve and reported are as follows:

(*a*) Duration of test,

(*b*) Breakdown voltage,

(*c*) Temperature of specimen at breakdown, and

(*d*) Rate of temperature rise during test.

The report shall also include a description of the specimen and its preparation, the thickness of the insulation, and the number of layers of insulation.

ELONGATION

(In the Case of Bias-Cut Material)

Scope

26. This method is intended to determine the effect of mechanical tension on bias-cut varnished cloths and tapes. This test is not applicable to tapes of less than 1.27 cm. (0.5 in.) in nominal width.

Apparatus

27. The apparatus required for the test shall consist of a pair of clamps for gripping the ends of the specimen. The clamps shall not be less than 5.08 cm. (2.0 in.) in width and one shall be provided with means for attaching to a fixed support and the other with means for affixing suspended weights. See Fig. 1 for suggested form of clamp.

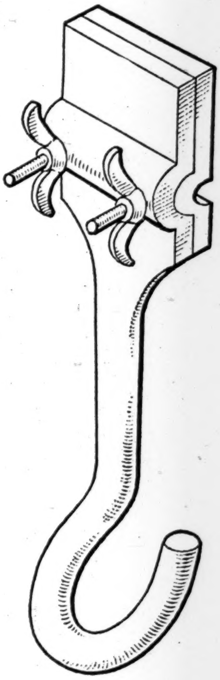

FIG. 1.—Clamp for Elongation Test.

Specimens

28. (*a*) In the case of bias-cut cloths, specimens shall be cut in the direction of the length from the samples selected in accordance with Section 3. They shall not exceed 3.81 cm. (1.5 in.) in width and shall be at least 91.44 cm. (36 in.) in length.

(*b*) In the case of bias-cut tapes, specimens shall be samples selected in accordance with Section 3 and they shall not exceed 3.81 cm. (1.5 in.) in width. Tapes of greater width than this shall be cut to 3.81 cm. (1.5 in.) or less before testing.

NOTE.—Strips of "Scotch tape" make a satisfactory method for marking the gage length on the elongation test specimens.

Elongation

29. A gage length of 50 cm. shall be marked on the test specimen and the specimen shall be fastened between two suitable clamps so that the gage length is centrally located between the clamps. The clearance distance between each gage line and the adjacent clamp shall be not less than 10 cm.

The test specimen shall be weighted with a specified load, M, (including the weight of the clamp) and at the end of 35 minutes the distance, L, between gage lines shall be measured and the load then removed.

Calculation

30. The percentage elongation is defined by the following formula:

$$\text{Elongation, per cent} = \frac{L - 50}{50} \times 100$$

in which L is in centimeters.

Dielectric Strength

31. After at least 20 min., but not more than 1 hr., following the removal of the load, five puncture voltages shall be taken within the gage length of the specimen in accordance with Section 15, using only the short-time test described in the Tentative Methods D 149 - 38 T.[1] The dielectric strength shall be calculated on the basis of the average thickness of the specimen determined immediately before the dielectric breakdown test.

Report

32. The report shall include the following:

(*a*) the load in pounds per inch width of tape;

(*b*) the percentage elongation;

(*c*) the average dielectric strength in volts per mil after elongation; and

(*d*) the temperature of the room during the elongation test.

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[1] See p. 1001.

POWER FACTOR AND DIELECTRIC CONSTANT

Scope

33. This method is intended to determine the power factor and dielectric constant of varnished cloths and tapes at frequencies not exceeding 70 cycles per second.

Definitions and Theory of Test

34. The definitions of dielectric power factor, dielectric constant and related terms, and the theory of test shall be as given in the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 36 T) of the American Society for Testing Materials.[1]

Electrodes

35. Flat, rigid, guarded electrodes, not over 10 sq. in. in area, of such size as to give the bridge sufficient sensitivity to detect readily a change in power factor of 0.0005, shall be used. The specimen shall extend beyond the guard electrode for a distance of at least four times the thickness of the specimen. The pressure shall be not less than 10 nor more than 20 lb. per sq. in.

Test Specimen

36. The test specimen may be tested in one thickness. Petrolatum may be used to avoid ionization. The petrolatum shall have a power factor at 80 C. of not exceeding 0.02 at 60 cycles, or a resistivity not less than 10^{12} ohms per centimeter cube at 80 C.

Conditioning of Specimen

37. The specimens shall be conditioned in one thickness by heating to 105 C. ± 3 C. for 1 hr. without vacuum, and then for 2 hr. at the same temperature in a vacuum having an absolute pressure not exceeding 1 mm. of mercury.

Procedure

38. Tests shall be made at room temperature of 25 to 30 C., and at 80 C. ± 1 C. The conditioned specimens shall be tested within 5 min. after removal from the vacuum container. The voltage gradient shall be 50 v. per mil. The method of measurement shall conform to that described in the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 36 T) of the American Society for Testing Materials.[1]

Number of Tests

39. Three specimens shall be tested and the average shall be taken.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 955 (1936); also 1938 Book of A.S.T.M. Tentative Standards p. 1071.

Report

40. The report shall include the following:

(*a*) *Test Conditions.*—The frequency in cycles per second, the temperature in degrees Centigrade, relative humidity in per cent, the conditioning of the specimen, size of electrodes, pressure on electrodes, voltage gradient in the dielectric while under test.

(*b*) *Specimen.*—Capacitance of specimen in micro-microfarads, effective area of specimen electrodes, average thickness of specimen between electrodes.

(*c*) Power factor, dielectric constant, and loss factor of each specimen, and the average.

(*d*) Method of measurement.

RESISTANCE TO OIL

Scope

41. This method is intended to determine the effect of oil on the varnish film and dielectric strength of the cloths or tapes.

Specimens

42. One specimen 30.48 cm. (12.0 in.) in length and not exceeding 3.81 cm. (1.5 in.) in width shall be cut from each of the rolls selected in accordance with Section 2.

Procedure

43. The specimens shall be immersed for 15 min. in a specified oil maintained at a temperature of from 97 to 103 C. At the end of this time, the specimens shall be removed from the oil, allowed to cool for at least 30 min. to room temperature and any excess oil removed by placing between blotters without any sliding.

Examination

44. The varnish film shall be examined for disintegration in the oil and flaking either in the oil or on the blotter. Disintegration in the oil may be detected by examination of the used oil for turbidness.

NOTE.—The oil may be considered turbid if a sample of used oil filtered through filter paper is distinctly less transparent than an unfiltered sample of the unused oil when the two samples, in identical containers, are held in front of a diffused light. Flaking along the cut edges of tapes shall not be considered as disintegration of the varnish film.

Dielectric Strength

45. Specimens which have been allowed to cool at least 30 min. may be tested for dielectric strength any time within a period of 4 hr. after removal from the oil. Five puncturing voltages shall be

taken on the specimens in accordance with Section 15, using only the short-time test described in the Tentative Methods D 149 – 38 T.[1] The dielectric strength shall be calculated on the basis of the average thickness of the specimen determined immediately before the dielectric breakdown test.

Report

46. The report shall include the following:

(*a*) The type of oils used (preferably including the flash point determined in accordance with the Standard Method of Test for Flash and Fire Points by Means of Open Cup (A.S.T.M. Designation D 92) of the American Society for Testing Materials).[2]

(*b*) The temperature of the oils.

(*c*) Results of the physical examination of the film (Section 36).

(*d*) The percentage increase in average thickness due to oil tests.

(*e*) The average dielectric strength in volts per mil after the oil tests.

WEIGHT

Weight

47. Specimens of sufficient size to weigh not less than 5 g. (0.18 oz.) shall be accurately weighed on an analytical balance and the weight shall be reported on some commercial unit basis such as, the weight per square yard, the weight per gross yard per 1 in. in width or the weight per roll.

THREADS PER INCH

Count

48. The count or threads per inch of the varnished cloth or varnished cloth tape shall be determined separately on the warp and filling by counting a space of not less than 1 in. (2.54 cm.) in at least five different places in the sample strip (or strips). The average of the five determinations shall be the count.

Report

49. The results of the warp count and the filling count shall be reported separately as threads per inch.

NOTE 1.—The warp threads in straight-cut materials are the threads which are parallel with the length dimension, while in bias-cut materials the warp threads are parallel with the seams and jointed selvages.

NOTE 2.—Before counting black, varnished materials it will be necessary to remove the varnish film with a knife blade or other suitable instrument. Liquid varnish removers are unsuitable for this purpose as they cause a swelling of the fibers and a shrinkage of cloth with a consequent increase in threads per inch; therefore, the films must be removed mechanically.

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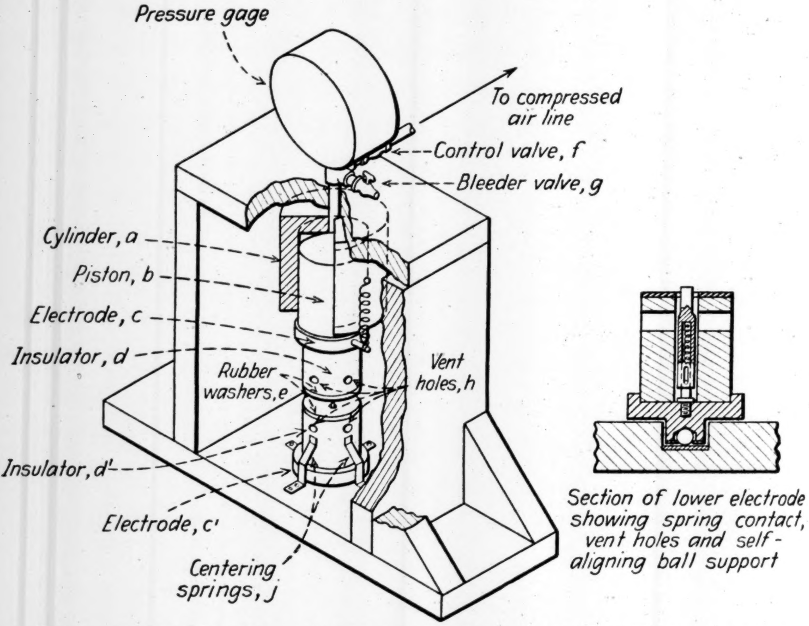
[1] See p. 1001.

[2] **1936 Book of A.S.T.M. Standards, Part II, p. 892.**

APPENDIX

APPARATUS FOR MAKING DIELECTRIC STRENGTH TESTS ON INSULATING TAPE

Figure A1 illustrates a single-shot tester for making dielectric strength tests on insulating tape. In this device the tape is held under pressure between rubber washers while the voltage is applied, the pressure being supplied by compressed air operating on a piston, *b*, in a cylinder *a*. The piston is connected to the upper electrode, *c*. The lower electrode *c′*, is mounted on the insulated base. The electrodes terminate in $\frac{1}{4}$-in. brass rods having flat ends with edges rounded to a radius of $\frac{1}{32}$ in. These electrode rods move against light springs. This insures a positive contact between electrode and tape. The electrode rods are surrounded by insulating blocks, *d* and *d′*, having vent holes, *h*, for the dissipation of the gases generated by breakdown. These insulating blocks are faced with soft rubber washers, *e*, which can be detached and replaced as necessary.


Pressure gage
To compressed air line
Control valve, f
Bleeder valve, g
Cylinder, a
Piston, b
Electrode, c
Insulator, d
Rubber washers, e
Vent holes, h
Insulator, d′
Electrode, c′
Centering springs, j

Section of lower electrode showing spring contact, vent holes and self-aligning ball support

FIG. A1.—Single-Shot Tester for Dielectric Strength Test on Insulating Tape.

The lower electrode assembly is lined up with the upper electrode assembly by centering springs, *j*, the position of which is adjustable. This lower assembly is also free to rock very slightly on a single ball support. This insures perfect contact and equalization of pressure when the electrode assemblies come together.

The upper electrode assembly is normally held clear of the lower assembly by two small springs so that tape may be readily inserted or withdrawn or moved to a new position of test. The piston, *b*, is smooth, without rings, and permits just enough leakage of air so that the pressure may be quickly adjusted and readily held at any desired value below the maximum available.

Where compressed air is not available, pressure may be exerted by a hand-operated lever attached to the upper, or movable, electrode assembly.

Another form of tester, known as the multiple-electrode type, clamps a long piece of tape under pressure between two insulating blocks, and has ten sets of electrodes spaced at intervals along the test specimen.

TENTATIVE METHODS OF TESTING FLEXIBLE VARNISHED TUBING USED FOR ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 350 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1932; Revised, 1935, 1937, 1938.

Scope

1. These methods cover the testing of flexible varnished tubing (Note) used as electrical insulation for leads on electrical apparatus.

Note.—The term "varnished tubing" as here used refers to braided cotton sleeving coated, or impregnated and coated, with lacquer or a combination of lacquer and varnish or other similar coatings.

SAMPLING

Sampling

2. (*a*) A sufficient number of the pieces of tubing to total not less than 1.83 m. (6 ft.) in length shall be selected from each 305 m. (1000 ft.) in the shipment, but in no case shall less than 1.83 m. (6 ft.) be taken from a shipment and the pieces shall be selected in such a manner as to be representative of the shipment.

(*b*) The number of specimens required for purpose of tests shall be cut from the pieces selected in accordance with Paragraph (*a*) and care shall be taken to select material which is free from abnormal defects such as blisters, wrinkles, cracks, etc.

CONDITIONING

Conditioning

3. (*a*) Test specimens shall be stored for at least 2 hr. in air maintained at a temperature between the limits of 20 and 30 C. (68 and 86 F.), before testing.

(*b*) If the relative humidity of the air is in excess of 55 per cent, then the specimens for the dielectric strength test shall be conditioned in air which is maintained at a relative humidity between the limits of 50 to 55 per cent in a temperature range of 20 to 30 C. (68 to 86 F.) for a period of 48 hr. If a conditioning cabinet is used, one specimen at a time shall be withdrawn and tested immediately for dielectric strength.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

NOTE.—A saturated solution of sodium-dichromate is a suitable humidifying agent for obtaining these limits when used under the conditions specified in Section 11 (*b*) of the Standard Methods of Test for Insulation Resistance of Electrical Insulating Materials (A.S.T.M. Designation: D 257) of the American Society for Testing Materials.[1]

DIMENSIONS

Gage Rods and Micrometer

4. (*a*) Standard gage rods with hemispherical ends and a 1-in machinist's type micrometer with ratchet device and having anvil and spindle surfaces 0.25 in ±0.001 in. in diameter shall be used.

(*b*) The standard gage rods shall be steel and shall have smooth surfaces. A set of two is required for each size of tubing. Each rod in a set shall have a diameter within ±0.0002 in. of the diameters listed as maximum and minimum in the following table:

A.S.T.M. STANDARD SIZES FOR FLEXIBLE VARNISHED TUBING.

	INSIDE DIAMETER, IN.		
SIZE	MAXIMUM	MINIMUM	NOMINAL
No. 0	0.347	0.325	0.330
No. 1	0.311	0.289	0.294
No. 2	0.278	0.258	0.263
No. 3	0.249	0.229	0.234
No. 4	0.224	0.204	0.208
No. 5	0.198	0.182	0.186
No. 6	0.178	0.162	0.166
No. 7	0.158	0.144	0.148
No. 8	0.141	0.129	0.133
No. 9	0.124	0.114	0.118
No. 10	0.112	0.102	0.106
No. 11	0.101	0.091	0.095
No. 12	0.089	0.081	0.085
No. 13	0.080	0.072	0.076
No. 14	0.070	0.064	0.066
No. 15	0.063	0.057	0.059
No. 16	0.055	0.051	0.053
No. 17	0.049	0.045	0.047
No. 18	0.044	0.040	0.042
No. 19	0.040	0.036	0.038
No. 20	0.036	0.032	0.034

NOTE.—The minimum inside diameters in this table are the same as the diameters of copper wire for corresponding A.w.g. or B. & S. gage sizes.

Test Specimens

5. Test specimens of any convenient length shall be cut from the samples obtained in accordance with Section 2.

Procedure

6. (*a*) *Inside Diameter.*—The minimum gage rod for the size tubing under test shall pass into the specimen for a distance of 5 in. without expanding the wall of the tubing. If the rod has a fairly snug fit, then the specimen has an inside diameter equal to the diameter of the rod. If, however, the minimum gage rod fits loosely, then the maximum gage rod shall

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 174.

be inserted into the specimen. If the maximum gage rod passes freely into the specimen for a distance of 5 in. with a fairly snug fit or if it expands the wall of the specimen, then the tubing shall be considered to be of that size which falls within the limits of the maximum and minimum inside diameters as represented by the gage rods.

(*b*) *Wall Thickness.*—A standard gage rod which will pass freely into the tubing shall be inserted in the specimen. The micrometer shall then be applied over the specimen, and a reading taken by following the procedure specified in Method A of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 - 36 T) of the American Society for Testing Materials.[1] The average of five micrometer readings shall be obtained. The wall thickness shall be considered to be one half the difference between the average micrometer reading and the diameter of the gage rod.

(*c*) *Outside Diameter.*—The outside diameter of the specimen shall be considered to be the sum of the estimated inside diameter and twice the wall thickness (Paragraph (*b*)). The inside diameter shall be estimated from the fit of the maximum and the minimum gage rods (Paragraph (*a*)).

Report

7. The report shall include the following:

   (*a*) The size of the tubing,
   (*b*) The wall thickness in inches, and
   (*c*) The outside diameter in inches.

DIELECTRIC STRENGTH

Dielectric Strength

8. Except as specified below in Sections 9 to 13, the dielectric strength shall be determined in accordance with the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 - 38 T) of the American Society for Testing Materials.[2]

Electrodes and Test Specimens

9. (*a*) A straight standard annealed copper wire shall serve as the inner electrode in a specimen of convenient length. The nearest A.w.g. size of wire shall be selected which will fit snugly without stretching the tubing. The wire shall be free of bends to avoid a binding action on the tubing as it is being slipped onto the wire. After the tubing has been placed on the copper wire, strips of metal foil 2.54 cm. (1 in.) in width shall be tightly wrapped on the outside at a distance of not less than 7.62 cm. (3 in.) apart and at least 7.62 cm. (3 in.) from the ends of the specimen.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, p. Part I, 1026 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1196.

[2] See p. 1001.

(*b*) The metal foil shall have a thickness not to exceed 0.0005 in. and the first turn of the foil applied to the tubing shall be wiped snugly against the tubing. Two more turns of the foil shall then be wound over this first turn, leaving a free end of $\frac{1}{2}$ in. to which the electrical connection shall be made during the test.

Note.—The standard gage rods should never be used as the inner electrode. The arc which forms when the tubing punctures will invariably raise a pimple of melted metal on the surface of the rod, spoiling it for use as a standard.

Surrounding Medium

10. The tests shall be made in air with the specimen at room temperature.

Procedure

11. Tests shall be made by the short-time method. Voltage shall be increased at the rate of 0.5 kv. per sec.

Number of Tests

12. Ten tests shall be made and the dielectric strength shall be the average of the ten breakdown voltages.

Report

13. The report shall include the following:

(*a*) Total volts at each puncture,
(*b*) The average, maximum, and minimum puncturing voltages,
(*c*) The room temperature, and
(*d*) The percentage relative humidity.

HEAT ENDURANCE

Test Specimens

14. Not less than ten test specimens, each 15.24 cm. (6 in.) in length shall be cut from the samples obtained in accordance with Section 2.

Note.—If the heat endurance is in excess of 120 hr., additional specimens will have to be cut.

Procedure

15. (*a*) The specimens shall be placed in a uniformly heated electric oven of the analytical type in which the temperature is maintained between the limits of 105 and 110 C. (221 and 230 F.). Two specimens shall be removed at the end of 24 hr. and every 24 hr. thereafter until failure occurs. After cooling to room temperature of approximately 20 C. (68 F.), each specimen shall be bent through 180 deg. over a rod having a diameter as shown in the following table:

Size	Diameter of Test Rod, in.
Nos. 0 to 5, incl.	$\frac{5}{16}$
Nos. 6 to 11, incl.	$\frac{1}{4}$
No. 12 and smaller	$\frac{1}{8}$

(*b*) The number of hours of baking at which first cracking across the specimen occurs shall be noted and reported. Any side cracking occurring because of the flattening of the specimen on the rod shall be disregarded.

SMOLDERING

(In the case of Grades A and B tubing)

Apparatus

16. The apparatus required for the smoldering test shall be a bunsen burner and a suitable support for holding the specimen.

Test Specimens

17. At least three test specimens 9.16 cm. (4 in.) in length shall be cut from the samples obtained in accordance with Section 2.

Procedure

18. (*a*) A gage length of 2.54 cm. (1 in.) shall be marked on the test specimen at least 2.54 cm. (1 in.) from the end of the specimen. The specimen shall be held mechanically in a horizontal position in still air.

NOTE.—Any metal rod inserted into the specimen for convenience in supporting it must not enter the region spanned by the gage length.

(*b*) The blue flame of the bunsen burner shall be applied to the unsupported end of the specimen until the specimen is thoroughly ignited. The burner shall then be removed. As soon as the leading edge of the flame of the tubing reaches the first gage mark, the flame shall be extinguished with a puff of breath. When all smoldering and smoking has ceased, the distance from the second gage mark to the edge of the charred varnish shall be measured. This measured distance shall be subtracted from 2.54 cm. (1 in.) and the difference shall be considered the distance of smoldering. If the smoldering extends beyond the second gage mark, the smoldering distance shall be reported as over 2.54 cm. (1 in.).

Report

19. The distance of smoldering to the nearest 1.5 mm. ($\frac{1}{16}$ in.) shall be reported.

RATE OF BURNING

(In the case of non-flammable or flame-resistant tubing, Grade C)

Apparatus

20. The apparatus required for the rate of burning test shall be a bunsen burner, a stop watch, and a suitable support for holding the specimen.

Test Specimens

21. At least three test specimens 9.16 cm. (4 in.) in length shall be cut from the samples obtained in accordance with Section 2.

Procedure

22. (*a*) A gage length of 2.54 cm. (1 in.) shall be marked on the test specimen at least 2.54 cm. (1 in.) from the end of the specimen. The specimen shall be held mechanically in a horizontal position in still air.

NOTE.—Any metal rod inserted into the specimen for convenience in supporting it must not enter the region spanned by the gage length.

(*b*) The blue flame of the bunsen burner shall be applied to the unsupported end of the specimen until the specimen ignites. The burner shall then be removed and the time in seconds for the leading edge of the flame to travel over the gage length of 2.54 cm. (1 in.) shall be observed with the stop watch. The rate of burning shall be defined as the number of seconds required to burn a length of 2.54 cm. (1 in.) of the specimen.

Report

23. The rate of burning for each specimen shall be reported.

TENTATIVE METHODS OF TESTING VARNISHES USED FOR ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 115 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1921; REVISED, 1922, 1923, 1924, 1925, 1926, 1928, 1929, 1930, 1931, 1934, 1935, 1936, 1938.

Scope

1. **These tests are intended for varnishes which are applied by brushing, dipping or spraying, and are primarily for the purpose of providing electrical insulation.**

DENSITY

Density

2. The density of the varnish shall be measured in grams per cubic centimeter at 25 C. ± 1 C. and recorded to the nearest 0.001 g. per cu. cm. using a wide-mouthed 25-ml. pycnometer of the Hubbard-Carmick type. The volume of the pycnometer shall be obtained by weighing the pycnometer first empty and then filled with distilled water at 25 C., and dividing the difference in weight by 0.997. The density shall be determined by dividing the weight of varnish by its volume. For convenience and accuracy a curve shall be plotted for each pycnometer showing relation between weight of pycnometer plus varnish and the density.

NOTE.—The Hubbard-Carmick type of pycnometer permits the escape of air bubbles from the more viscous types of varnishes.

VISCOSITY

Apparatus

3. Viscosimeters used in this test shall be kept calibrated over the range of viscosity of the varnishes to be tested by means of oils verified as to absolute viscosity at 25 C. by the National Bureau of Standards. A calibration curve showing the relation between viscosity in absolute units and the instrument readings shall be used.

NOTE.—A description of the MacMichael viscosimeter as remodeled and improved for varnish testing together with directions for its calibration in absolute units appears in Appendix I.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

Test Specimens

4. The test specimen shall consist of a portion of a varnish sample sufficient for several determinations of viscosity and maintained at a temperature of 25 C. ± 1 C.

NOTE.—The sample should be kept in a nearly filled, tightly sealed container until used for test in order to avoid skin formation and the escape of solvents.

Procedure

5. (*a*) A specimen shall be poured from the sample into the viscosimeter cup which shall be kept immersed in water at such a temperature that the temperature of the varnish may be quickly brought to 25 C. ± 0.2 C. The test shall be made immediately to avoid evaporation or formation of skin on the surface of the varnish. Two specimens shall be tested and the mean value reported, provided the average deviation of a single observation from the mean is not greater than 2 per cent. Otherwise, the instrument and method used shall be checked, and additional tests made until average deviation from the mean does not exceed 2 per cent.

(*b*) The viscosity shall be determined at 25 C. ± 0.2 C. and the results shall be stated in terms of absolute viscosity, centipoises (Note).

NOTE.—The absolute viscosity of a material or its viscosity in absolute nuits (c.g.s., poises) has been defined as the force in dynes required to move, at a velocity of 1 cm. per sec., one surface having an area of 1 sq. cm. past another parallel like surface 1 cm. away, overcoming the resistance to shear of the material filling the space between. One centipoise = 0.01 poise.

Report

6. The report shall include the following.

(*a*) Individual readings in centipoises and corresponding varnish temperatures to nearest 0.1 C.

(*b*) Mean value in centipoises.

(*c*) Average deviation of individual observations from the mean in centipoises and in percentage of the mean.

(*d*) Type of viscosimeter used.

FLASH POINT

Flash Point

7. The flash point shall be determined in accordance with the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93) of the American Society for Testing Materials.[1]

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 897.

THICKNESS MEASUREMENTS

Thickness

8. All test specimens on which thickness measurements are to be determined shall be measured for thickness in accordance with Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 - 36 T) of the American Society for Testing Materials.[1]

TIME OF DRYING

Test Specimens

9. (*a*) Specimens for this test shall be films of varnish coated on thoroughly clean and smooth strips of copper $1\frac{1}{4}$ in. wide and 8 in. long and 0.005 ± 0.0003 in. in thickness. The thickness of the cleaned copper strip shall be measured before the strip is dipped into the varnish.

(*b*) The varnish shall stand in a covered tank for a sufficient length of time to be free of air bubbles but not to exceed 1 hr., before the copper strips are dipped. The copper strips shall then be dipped once in the varnish at a temperature of approximately 25 C. (77 F.) and withdrawn slowly and uniformly (about 15 in. per min.). The consistency of the varnish shall be first so adjusted by trial that, when dry as determined in accordance with Section 11, the average thickness of the film of varnish on each side of the copper strip shall be between the measured limits of 0.0009 and 0.0010 in. The average thickness shall be calculated from the average of at least six thickness readings taken in the middle half portion of the length of the strip. No thickness readings shall be taken within $\frac{1}{8}$ in. of either edge of the strip.

NOTE.—It is recognized that the thickness cannot be measured with the precision stated but a close control of the thickness of the varnish film is desired. With the use of the micrometer specified in Section 8, the actual average thickness may be expected to be the measured average thickness plus or minus 0.0002 in.

Procedure

10. (*a*) Specimens of air-drying varnish shall be dried in dust-free air at a temperature of approximately 25 C. (77 F.).

(*b*) In the case of baking varnishes, six specimens shall be dipped and allowed to drain at a temperature of approximately 25 C. (77 F.) until the varnish is set as indicated when the impression left on the surface by pressing lightly thereon with a finger at a point approximately 2 in. from the bottom will not become obliterated by further flow of the material. They shall then be dried in dust-free air in an oven at 105 to 110 C. (221 to 230 F.). At the end of the first 30 min. and, again at the end of each 10-min. period thereafter, one specimen shall be taken from the oven and examined. In the case of slow-drying varnishes, this 10-min. period may be lengthened at the discretion of the operator.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1026 (1936); also 1938 Book of A.S.T.M. Tentative Standards ,p. 1196.

NOTE.—The size of oven and the amount of ventilation have a considerable effect on the drying time of varnishes. For this reason the analytical type of electrically-heated oven should be used, and if different ovens are used they should be checked with control samples in order to determine whether they will yield comparable results.

Time of Drying

11. The varnish shall be considered dry when a piece of kraft paper 1½ in. in width, 6 in. in length, and approximately 0.0025 in. in thickness does not adhere to the varnish when it is pressed on the surface of the varnish for 1 min. by a cylindrical 1-lb. weight, 1 in. in diameter. The kraft paper shall be applied in the vicinity of the center of the specimen and at right angles to it. The test shall be made at a temperature of approximately 25 C. (77 F.).

NOTE.—Certain types of varnishes dry with what is commonly known as a "tack," but these types are rare. However, when testing them for drying time, it will be found that the kraft paper adheres to the varnish film and offers a certain amount of resistance to removal. On continued drying, the resistance to removal reaches constancy and is not changed by further drying. Therefore, the drying time is reported as the number of hours required to first reach constancy and the varnish should be reported as drying with a "tack."

DIELECTRIC STRENGTH OF VARNISH IN THE SOLID STATE

Scope

12. (*a*) This test is intended to determine the suitability of an insulating varnish for use in certain electrical applications by taking the dielectric strength test under different conditions of temperature and after immersion in water. The test provides for the determination of dielectric strength under the following conditions:

(*1*) At room temperature in air,
(*2*) At 75 C. in air, and
(*3*) At room temperature after immersion in water of approximately 25 C. (77 F.) for a period of 24 hr.

NOTE.—Dielectric strength determinations may also be made in oil at room temperature and at 75 C. With this exception, the procedure for test is the same as outlined here. If tests are made in oil, this fact shall be definitely reported with the results.

(*b*) Much more information about a varnish can be obtained by making the test under all three conditions than by making it under only one condition. The relation which the dielectric strength tests for a given varnish show to one another, is of quite as much significance as the values for the different tests considered separately.

(*c*) Except as specified below in Sections 13 to 16, the dielectric strength shall be determined in accordance with the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149-38 T) of the American Society for Testing Materials.[1]

Electrodes

13. Tests shall be made between two metal cylinders, 2 in. in diameter,

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[1] See p. 1001.

and with edges rounded to a radius of $\frac{1}{4}$ in. The pressure between electrodes shall be approximately 1.1 lb. (0.5 kg).

Test Specimens

14. (*a*) Specimens for the dielectric strength tests shall be prepared by dipping pieces of kraft paper 8 in. square and 0.003 in. in thickness into the varnish which shall be at a consistency to give the thickness specified in Paragraph (*e*).

NOTE.—The paper used shall be that which is commercially known as No. 1 sulfate kraft. The surface of the paper shall be smooth, free from pimples or lumps, and reasonably free from hairy fibers. The paper shall also be free from conducting particles, slime spots, creases, cuts, specks or other "paper defects."

(*b*) Each specimen shall be dipped twice, as specified in Section 9 (*b*), once in each direction, in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish shall be dried in dust-free air after each dip at a temperature of approximately 25 C. (77 F.) for a period equal to six times the drying time recommended by the manufacturer or, in the absence of such information, six times the drying time determined in accordance with Section 11.

(*d*) Specimens of baking varnish shall be drained and then baked in dust-free air at a temperature of 105 to 110 C. (221 to 230 F.) after each dip for a period equal to three times the drying time recommended by the manufacturer or, in the absence of such information, three times the drying time determined in accordance with Section 11.

(*e*) The final thickness of the specimen shall be 0.006 ± 0.0005 in.

Conditioning

15. The dielectric strength shall be determined under the following conditions:

(*a*) At room temperature in air (Note 1),

(*b*) At 75 C. in air (Notes 1 and 2), and

(*c*) At room temperature on specimens which shall have been immersed in water at a temperature of approximately 25 C. (77 F.) for a period of 24 hr. (Note 3).

NOTE 1.—Dielectric strength determinations may also be made in oil at room temperature and at 75 C. With this exception the procedure for test is the same as outlined above. If tests are made in oil, this fact shall be definitely reported with the results.

NOTE 2.—The tests at 75 C. shall be made in air in an analytical type of electrically-heated oven. The electrodes shall be at oven temperature before the test is started. Tests should be started 15 min. after the specimen has been introduced into the oven and placed between the electrodes and completed before 15 min. additional have elapsed.

NOTE 3.—In testing specimens after immersion in water, only one specimen should be removed from the water at a time. The specimen after removal from the water should be carefully dried by placing between sheets of dry blotting paper and pressing down gently with the hand over the entire surface. If necessary, the blotting procedure should be repeated until the specimen is free from surface moisture. The specimen should then be tested immediately. If specimens are allowed to remain out of water for even a short time before testing, they dry out to a greater or less extent and the test is apt to be misleading.

Procedure

16. (*a*) Tests shall be made by the short-time method. The voltage shall be increased at the rate of 0.5 kv. per sec.

(*b*) Ten punctures shall be made, five on each of two specimens.

(*c*) After testing, the thickness of the specimen shall be determined by making five measurements on a strip cut diagonally across the specimen. The measurements shall be spaced approximately equally along the strip. The average of the five measurements shall be considered as the thickness of the specimen.

HEAT ENDURANCE TEST

Test Specimens

17. (*a*) Specimens shall be prepared by dipping into the varnish, strips of thoroughly cleaned and smooth copper 8 in. in length, 1 in. in width and 0.005 ± 0.003 in. in thickness. The consistency of the varnish shall be adjusted previously by trial so that, when dry as determined by Section 11, the average thickness of the film of varnish on each side of the copper strip shall be between the limits of 0.0009 and 0.0010 in. The average thickness of each film of varnish shall be calculated from the average of at least six thickness readings taken in the middle half portion of the length of the strip. No thickness readings shall be taken within $\frac{1}{8}$ in. of either edge of the strip.

NOTE.—With the specified micrometer, the thickness measurement is accurate to within plus or minus 0.0002 in. The close limits stated are intended for a close control of thickness which is necessary for this test.

(*b*) Each specimen shall be dipped in the varnish at a temperature of approximately 25 C. (77 F.) and withdrawn slowly and uniformly (15 in. per min.). The varnish shall be dried in air (if an air-drying varnish) or baked (if a baking varnish) in an oven at 105 to 110 C. (221 to 230 F.) until dry as determined by Section 11. As soon as the first coat of varnish is dry, and the specimen is at room temperature, it shall be dipped again in the varnish in the reverse direction so as to give a uniform thickness of coating. The second coat of varnish shall be dried in the same manner as the first coat. When the second coat of varnish is dry, the thickness of the specimen shall be determined. The measured average thickness of varnish on each side of the metal shall be between the limits of 0.0017 and 0.0021 in. The average thickness of each film of varnish shall be calculated from the average of at least six readings taken in the middle half portion of the specimen.

Procedure

18. (*a*) The specimens shall be placed in a uniformly-heated oven, in which the temperature is maintained at 105 to 110 C. (221 to 230 F.). A specimen shall be removed at the end of the first 24 hr. and every 24 hr. thereafter.

NOTE.—Because of temperature variations between different levels in the oven, the specimen should be placed in the oven with the 8-in. dimension horizontal and the 1-in. dimension vertical. All specimens should be at the same level in the oven.

(*b*) Each specimen, after heating, shall be tested at a temperature of approximately 25 C. (77 F.) by bending it through 180 deg. around a rod 0.125 in. in diameter.

Report

19. The number of hours of baking of the specimen which first showed cracking of the varnish film shall be reported, together with the make and type number of the oven used.

NOTE 1.—This size of oven and the amount of ventilation have a considerable effect on the heat endurance of varnish films. For this reason the analytical type of electrically-heated oven should be used, and if different ovens are used they should be checked with control samples in order to determine whether they will yield comparable results.

NOTE 2.—The temperature of the oven should be held as closely as possible to the mean (107.5 C., 225.5 F.). A difference of 5 deg. Cent. (9 deg. Fahr.) in this temperature range, when continuously maintained, has a very considerable effect (approximately 25 per cent) on the life test of a varnish.

NOTE 3.—As the "grain" of the copper influences the result of the test, the specimens for the heat endurance test should be prepared by cutting the copper strips parallel with the direction of rolling.

OIL PROOF TEST

Test Specimens

20. (*a*) To test for the effect of oil, the specimens shall be prepared as prescribed in Section 17 (*a*).

(*b*) The specimens shall be dipped and dried as prescribed in Section 14 (*b*), (*c*) and (*d*).

Procedure

21. The effect of oil on the varnish shall be determined by immersing the specimens in transformer oil at a temperature of 105 to 110° C. (221 to 230° F.) for 48 hours and noting the effect on the varnish as indicated, for example, by wiping with a piece of dry white cloth.

NOTE.—Incipient disintegration of the surface of the varnish may sometimes be detected by examining the oil for turbidity. If a specimen of the used oil filtered through filter paper can be distinguished from an unfiltered sample of the used oil, when the two samples in identical containers are held in front of a diffused light, the oil is turbid.

DRAINING TEST

(Also known as "Working Viscosity" Test)

Test Specimen

22. A strip of sheet copper or brass 1½ in. in width, 14 in. in length, and 0.005 ± 0.0003 in. in thickness, shall be immersed in the

varnish at a room temperature of approximately 25 C. (77 F.) up to a line previously drawn across the strip 1 in. from the top. The sheet shall be withdrawn at a slow and uniform rate (about 15 in. per min.), care being taken that the varnish is free from air bubbles. The specimen shall be permitted to drain thoroughly at room temperature while suspended in a vertical position. It shall then be dried or baked (according to the type of the varnish) until dry as determined in accordance with Section 11.

Measurements

23. The thickness of the specimen in mils shall be measured at points 2 in., 7 in. and 12 in., respectively, from the line to which the specimen was immersed.

Report

24. The thickness of each film in mils at the three points specified in Section 23 shall be recorded. The difference between the thickness at the upper point (2 in.) and that at the lower point (12 in.) shall be taken as a measure of the variation in the film thickness caused by draining.

TEST FOR NON-VOLATILE MATTER BY WEIGHT

Apparatus

25. The apparatus required consists of a chemical balance, a glass thermometer having a range of 0 to 150 or 200 C. and accurate within 1 C., a constant-temperature oven of uniform temperature, a stoppered bottle and flat bottom metal drying dishes. Each metal drying dish shall have an inside diameter of approximately $2\frac{3}{4}$ in. (7 cm.) and a depth of approximately $\frac{5}{16}$ in. (8 mm.).

Note.—A standard single-friction tin can cover having a diameter of $2\frac{13}{16}$ in. is suitable for use as a drying dish.

Test Specimen

26. The specimen shall consist of approximately 1.5 g. (1.35 g. to 1.65 g.) of the sample of varnish taken from the shipment.

Procedure

27. (*a*) *Preparing the Specimens.*—A portion of the sample of varnish shall be placed in a stoppered bottle or weighing pipette and weighed. Approximately 1.5 g. (1.35 g. to 1.65 g.) shall be transferred from the weighed stoppered bottle to a weighed drying dish which has previously been heated for 30 min. at 135 C. and cooled in a desiccator. The stoppered bottle with the remaining contents shall be weighed again. The exact weight of the specimen transferred to the drying dish shall be determined by difference. A total of three specimens shall be prepared from the contents of the stoppered bottle.

(*b*) *Drying the Specimens.*—The specimens shall be placed in the constant temperature oven within 30 min. after preparation. The specimens shall be heated for a period of 3 hr. at the temperature designated, as follows:

Impregnating varnishes of the phenolic-resin type......	132 to 138 C.
Other types of insulating varnishes..................	105 to 110 C.

NOTE.—In a gravity type of oven which depends upon the natural circulation of air for uniformity of temperature, only one shelf must be used for supporting the specimens, and the bulb of the thermometer for indicating the temperature shall be in close proximity to the specimens.

(*c*) *Weighing the Dried Specimens.*—At the termination of the 3-hr. heating period, the specimens shall be removed to a desiccator for cooling to room temperature. Each specimen shall be weighed immediately upon removal from the desiccator.

(*d*) *Calculation.*—The ratio of the weight of the dried specimen to the weight of the specimen in the original state expressed as a percentage is the percentage of non-volatile matter by weight.

Report

28. The report shall include the following:

(*a*) The type of varnish;
(*b*) The oven temperature, and
(*c*) The percentage of non-volatile matter.

TEST FOR VOLATILE MATTER BY VOLUME

Scope

29. This test is intended to determine the volume percentage of volatile matter (solvent) in a varnish, and to afford a means of arriving at the volume composition of the varnish with respect to volatile (solvent) and non-volatile (base) constituents.

Procedure

30. (*a*) About 100 ml. of the varnish shall be distilled in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.[1] The distillation shall be "qualitative" instead of "quantitative" as given in Section 4 of the Standard Method D 86; that is, it is not necessary to record the volume of distillate recovered, or the temperature of the initial boiling point or end point.

(*b*) The distillation shall be continued until a suitable end point indicates that all the volatile matter (solvent) has been distilled off.

NOTE.—In the distillation of varnishes the end point differs with the various types and compositions. In all cases, however, the rate of distillation slows down as the end point is approached; and, when the end point is reached, acrolein (formed in the decomposition of the varnish base) is evolved and may be detected by its characteristic odor.

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 137.

In addition to the evolution of acrolein, the following phenomena are suitable indicators of end point:

(1) When the end point of the solvent is considerably lower than the initial boiling point of the base, the end point of the distillation is indicated by the temperature reaching a maximum and then starting to fall consistently.

(2) When the end point of the solvent and the initial boiling point of the base are too close, or overlap, the above temperature drop does not occur. The end point of the distillation is then indicated by a sudden foaming up of the residual base in the distillation flask; or, if the distillation has been accompanied by foaming, the end point is indicated by a breaking of surface tension with a consequent cessation of foaming.

Density.

31. The density of the volatile matter (solvent) recovered by distillation shall be determined in accordance with the procedure described in Section 2.

Volatile Matter by Weight

32. The difference between 100 per cent and the percentage of non-volatile matter determined in Sections 25 to 28 shall be calculated and recorded as the percentage of volatile matter by weight.

Volatile Matter by Volume

33. The percentage of volatile matter by volume shall be calculated from the formula:

$$x = \frac{AC}{B}$$

where

x = the percentage of volatile matter by volume;

A = the density of the original varnish, as determined in Section 2;

B = the density of the volatile matter (solvent) recovered by distillation, as determined in Section 31; and

C = the percentage of volatile matter by weight, as determined in Section 32

Accuracy

34. With proper care and attention to detail in making this test, differences occurring between different laboratories should not exceed 2 per cent for varnishes containing solvents which have end points not over 235° C. (455° F.), and should not exceed 4 per cent when the end point of the solvent is as high as 307.2° C. (585° F.).

DIELECTRIC STRENGTH OF VARNISH IN THE LIQUID STATE

Scope

35 (*a*) The purpose of the dielectric strength tests of varnish in the liquid state is to insure that the varnish is free from moisture and foreign matter such as might come from unclean shipping containers.

(*b*) Except as specified below in Sections 36 to 38, the dielectric strength shall be determined in accordance with the method for liquids described in the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149-38 T) of the American Society for Testing Materials.[1]

Conditioning

36. The temperature of the varnish when tested shall be the same as that of the room.

Procedure

37. (*a*) The sample of the varnish shall be shaken so that it will be thoroughly mixed before filling the test cup; the shaking shall be done gently to avoid the formation of bubbles.

(*b*) The cup shall be filled with varnish to a height of not less than $\frac{3}{4}$ in. above the top of the electrodes.

(*c*) The varnish shall be allowed to remain in the test cup until all air bubbles have disappeared.

(*d*) Voltage shall be applied and increased uniformly at the rate of approximately 3 kv. (r.m.s. value) per sec. until electrical breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

(*e*) After the breakdown and before removing the varnish from the test cup, the electrode surfaces shall be rubbed thoroughly with dry calendered tissue paper wrapped around a knife blade to provide stiffness. The test cup shall then be emptied and immediately refilled with the next filling of varnish to be tested.

(*f*) Five fillings shall be tested in conformity with the above procedure and the last filling of the cup shall drain the sample container.

Variations in Results

38. Differences as great as 15 per cent may occur between different laboratories in the results of this test. This is considered satisfactory in view of the purpose of the test.

Report

38. The report shall include the following:

(*a*) The kilovolts (r.m.s. value) at each electrical breakdown,

(*b*) The average value of the five breakdowns in kilovolts, and

(*c*) The mean deviation from the average value expressed as a percentage of the average breakdown value.

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[1] See p. 1001.

APPENDIX I

DESCRIPTION AND USE OF REMODELED MACMICHAEL VISCOSIMETER FOR DETERMINING VISCOSITY OF INSULATING VARNISHES

APPARATUS

The viscosity of varnishes may be determined by means of the remodeled MacMichael Viscosimeter shown in Figs. 1, 2 and 3. This instrument gives the viscosity values in terms of MacMichael degrees which are converted into absolute units of viscosity (centipoise) by means of the calibration curves of the various suspending wires.

In Fig. 1 the apparatus, consisting of the following parts, is shown unassembled:

A is the indicator by means of which the zero is adjusted and readings on scale *D* are taken.

B is the insulated wire suspension, the torsion of which measures the viscosity. The wire is fastened only at the bottom of its insulating sleeve *E'*. This is suspended by hanging it on points *P'*. (Ten wires of different size to cover various ranges of viscosities are supplied.)

C is the clamp screw which clamps the hollow spindle *E* to the sleeve *E'* which holds the torsion wire *B*.

D attached to hollow spindle *E* is the dial on which are calibrated the degrees MacMichael (300 deg. to the circumference). By means of this dial and indicator *A* the degrees deflection are determined as indicated in the method described below.

E is the hollow vertical spindle inside of which is the torsion wire sleeve *E'* which contains torsion wire *B*.

F is an oil-filled dash pot which acts as a brake to deaden oscillations and bring the suspension to rest quickly when making a determination. The dash pot swings between arm guides *F'* when the machine is assembled.

G is the brass disk which is attached to the bottom of vertical spindle *E*. Torsion wire *B* and *E'* is inserted into *E* and clamped with screw *C* and the disk *G* is then suspended in the liquid whose viscosity is being measured. Rotation of the sample cup *H* rotates the liquid and the rotating liquid exerts a certain force on the disk *G* partially rotating it and thus a torsion is produced in the wire suspension *B*, the deflection of which (or degree of torsion) is read from the scale on deflecting disk *D*.

H is the container which holds the sample. A locking device fastens it securely to *I* or *J*.

I is the water bath used for securing a uniform temperature in the liquid whose viscosity is being determined, when these viscosity measurements are desired at temperatures approximating that of the room (used on varnishes and oils).

J is the heating unit which is used in place of *I* when viscosity measurements are made at high temperatures (used on compounds).

K is the contact which carries the electric current to the heating unit cup *J*. It can be swung back when using cups *H* and *I* and when therefore electric heating is not desired.

L is the counter which indicates the revolutions per minute of the turntable *M*. A trip arrangement allows this counter to be lowered or raised, thus throwing the counter in or out of operation at will.

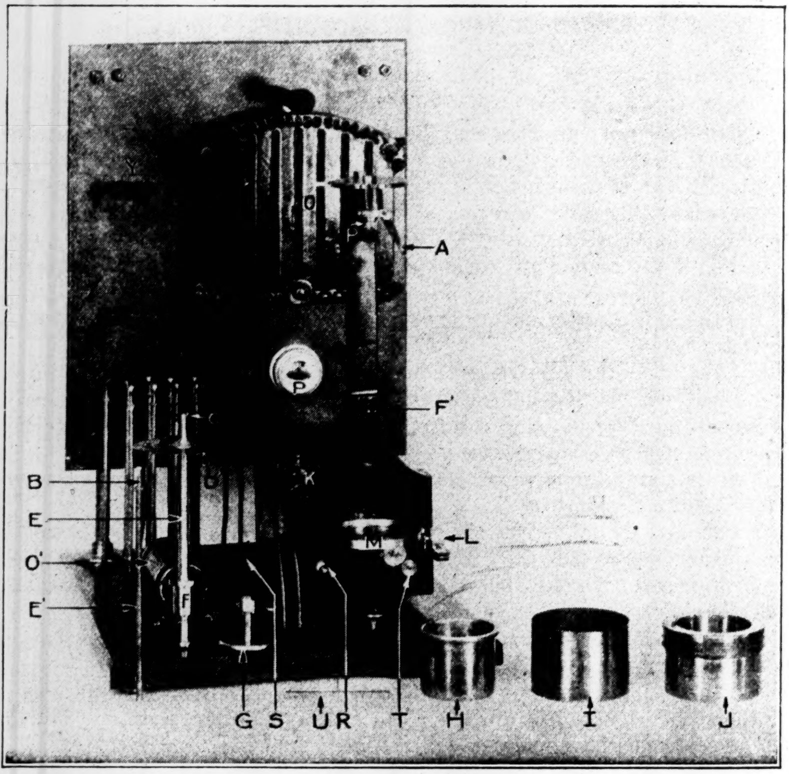

FIG. 1.—Improved MacMichael Viscosimeter Apparatus, Unassembled.

M is the rotating turntable in which *I* or *J* are set. A locking device (not shown) locks *I* or *J* securely to the turntable *M* so that when the turntable rotates the water bath or heating unit with the sample container also rotate.

N is the inclosing case under which is the motor and governor shown in Fig. 3. These operate turntable *M*.

O is a rheostat which controls the current going to the heating unit *J*.

O' is a rheostat controlling current for motor (shown only on remodeled instruments).

P is the knife switch (snap switch on new type machine) controlling the current for the heating unit *J*.

R is the push button which controls the electric current operating the motor shown in Fig. 3.

S is a leveling screw to level the instrument. Another such screw (not shown) is directly opposite to this one.

T is the governor screw that adjusts the speed of the motor by adjusting the governor shown in Fig. 3. In the remodeled apparatus the speed of rotation of turntable *M* can be decreased by moving the large gear in gear box away from the motor until pin of motor shaft is disengaged from slot of gear sleeve. The instrument is sent out with gear in low-speed position; to obtain high speeds shift gear toward motor until pin is engaged.

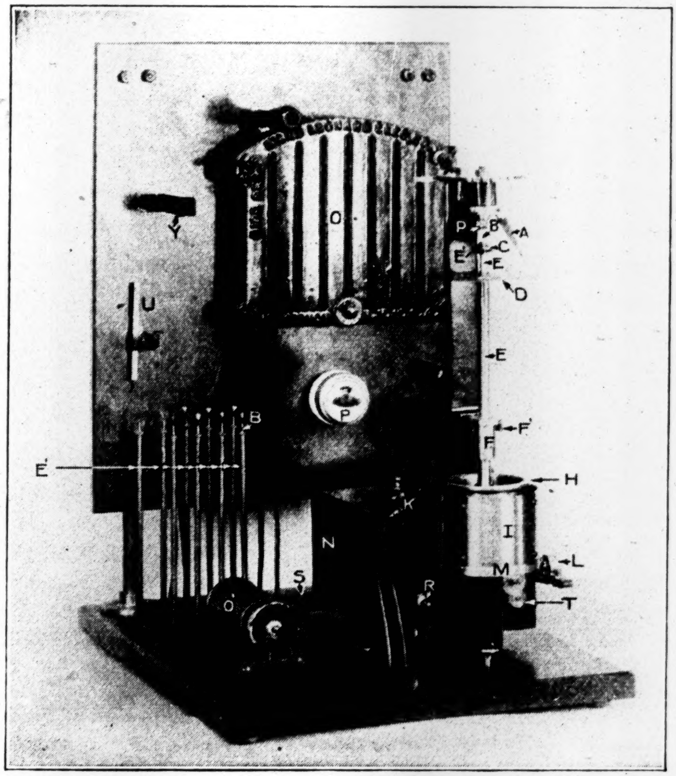

FIG. 2.—Improved MacMichael Viscosimeter Apparatus Assembled for Testing Varnish or Oil.

U is the measuring device used to measure the depth of the liquid in container *H*.

p are the projecting points on which the assembled spindle, namely, insulated torsion wire suspension *B* and *E'*, spindle and deflection dial *D*, and immersed disk *G* are suspended.

The apparatus is shown assembled in Fig. 2 for viscosity determinations on oil or varnish. Explanatory letters refer to the same parts as in Fig. 1.

In Fig. 3 are shown the internal structure and cup and heating unit assembled for testing compounds. The explanatory letters refer to the following:

V is the motor which operates the turntable *M*.

W is the governor controlling the speed of the turntable *M*.

X are the leads to connect instrument to 110-volt alternating current or direct current lighting circuit.

Y is the clamp holder for holding the spindle *E* with its dial *D*, when the machine is not in use (remodeled machines).

The heating unit *J* and the sample container, *H*, are here shown assembled as used in the viscosity determinations on compounds.

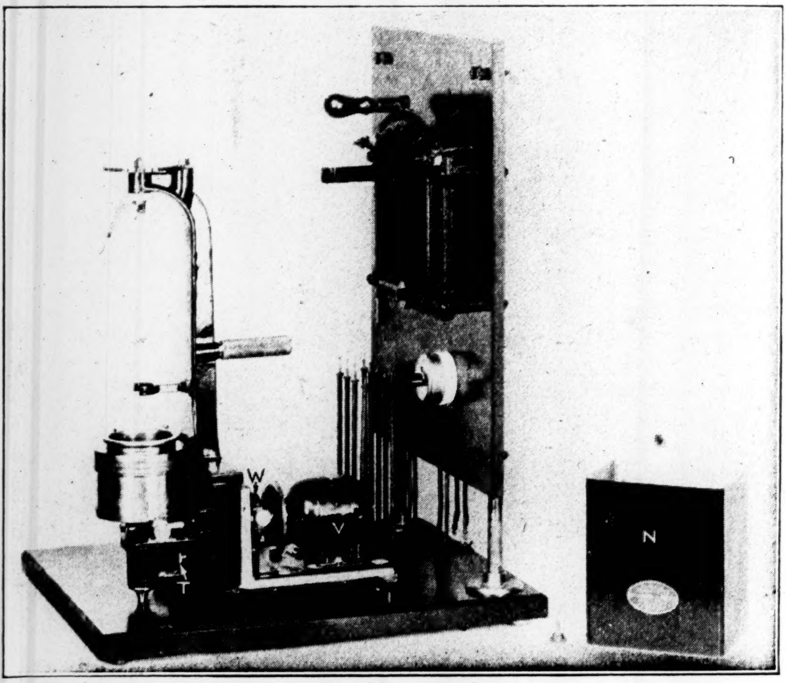

FIG. 3.—Improved MacMichael Viscosimeter Apparatus Showing Internal Structure and Cup and Heating Unit for Testing Compounds.

DIRECTIONS FOR MAKING VISCOSITY MEASUREMENTS ON VARNISH

Cups and disks must be perfectly clean. Otherwise reliable results cannot be obtained.

Dash pot *F* on the stem of the spindle should be two-thirds full of a medium grade of good machine oil (Etna Engine or Appollo) in order to dampen vibrations.

Use water bath *I* to secure and maintain the temperature of the sample in *H* when testing varnishes or oil.

Insert container *H* into water bath *I*. See that they are properly locked together, then lock bath *I* on turntable *M*.

Choose the proper torsion wire suspension for the liquid to be tested. Experience is the best guide to determine what suspension to use. Screw the disk *G* to the spindle *E*, and insert into *E* the proper insulated torsion wire suspension *E'*. Suspend these assembled parts from points *p* so the disk is suspended in the container *H*. Be sure to always suspend the wire on the points *p* with the flat side of the triangular button against the flat side of the supporting arm. The rounded surface of the triangle must face out towards the operator. Tightly fit the cover of the dash pot *F* on the arm guides F'.

See that the instrument is perfectly level. Use leveling screws *S* to adjust the instrument. The instrument is level when the suspended sleeve *E* swings exactly in the center of the hole of the cover on the dash pot.

Adjust the speed of the turntable to 60 r.p.m. This should be checked each time determinations are made. Use the governor screw *T* to adjust the speed of the motor. The gear in the gear box, referred to under *T* in the description of Fig. 1, should be in high speed position, that is, towards the motor. Use a stop watch to adjust the speed. After the speed is adjusted, lower the counter *L* so it will not operate during the following procedure.

NOTE.—The deflection is directly proportional to the speed of rotation. The 60 r.p.m. must therefore be maintained when the varnish, oil or compound is in the cup. It is, therefore, necessary to check first the revolutions per minute without the disk suspended in the sample, and again, when running a determination with the disk suspended in the sample. The motor must give the same number of revolutions per minute in each case and this value must be the same as was used for calibrating the suspension.

When the instrument is level adjust the indicator *A* to the zero mark on the dial *D*, when the spindle is suspended in the air, by moving the indicator as necessary. When the indicator has been set it must not be moved again until the test has been completed.

Fill the container *H* with the sample to be tested to a depth of 3.5 cm. A special device *U* is provided to measure this depth. Lay this device across the cup so the pointed end projects into the cup. When the surface of the liquid just touches the point, the depth of the liquid in the cup is 3.5 cm.

Raise or lower the temperature of the oil or varnishes to 21° C. by adding hot or cold water to the water bath, always stirring the sample well until a uniform temperature is secured. This is imperative. The sample may be stirred by rotating the sample cup frequently. It may also be stirred by lifting the spindle from the points *p* and stirring with the disk *G* holding the spindle by the barrel *E* and stirring by giving the disk an up-and-down movement in the sample cup. In the case of compounds, it is necessary to stir in this manner. In testing varnishes and oils, usually sufficient stirring can be obtained by rotating the cup while holding the barrel *E* to keep the disk stationary. If the spindle is removed from the points *p* it must always be suspended again with the same flat side of the supporting triangular button against the supporting arm so that the zero position is not changed.

If, when resuspending the spindle from points *p* it is noted that the zero point has moved, do not reset the indicator *A* as the change probably is due to some torsional effect produced by the sample. This may be especially noticed when testing compounds. Rotate the cup and take the reading without resetting the indicator.

When reading the thermometer have the bulb in the sample midway between the disk and the container wall and not resting on the bottom. Test the temperature at various points in the container to determine if a uniform temperature has been secured.

When a uniform temperature of 21° C. is secured, start the cup rotating by closing the switch *R*. Keep a hand on the switch and watch the scale on the disk *D*. If there is any danger that the deflection will go beyond the maximum limit for the suspension being used, open the switch immediately. Insert the next strongest wire suspension into the spindle and repeat as above indicated. When changing suspensions it is necessary to again set for zero. This may be accomplished without removing the sample, by simply removing the water bath, *I*, with its sample container, *H*, and then suspending the spindle with its new suspension on *p*, and leveling and adjusting as described above. It is necessary, of course, to thoroughly clean the disk, *G*, when doing this for if any varnish film should dry on the disk, the uneven or rough surface thus produced on the disk would cause an erroneous reading. A suspension wire should never be allowed to deflect beyond its maximum limit, for beyond this point a permanent set would be produced in the wire and a new calibration of the wire would have to be made or probably a new wire would have to be used. Table I gives a maximum and minimum limit for suspensions now in use. If the deflection is less than this minimum limit the next weakest suspension must be inserted and the test repeated. The reason for this is that at low deflections a change in slope appears on the calibration curve of the MacMichael degrees *versus* centipoises. The percentage error is magnified here and hence a reading that comes up higher in the calibration curve should be used. The maximum limit given may not be the limit to which it is permissible to deflect the wire in order to prevent its acquiring a permanent set. It, however, happens to be the limit of the calibration curve available for that suspension when the wire was calibrated.

TABLE I.—MAXIMUM AND MINIMUM LIMITS FOR SUSPENSIONS.

SUSPENSION NUMBER (B. & S. Gage No.)	MINIMUM DEFLECTION, DEG. MACMICHAEL	APPROXIMATE EQUIVALENT CENTIPOISE READING	MAXIMUM DEFLECTION, DEG. MACMICHAEL	APPROXIMATE EQUIVALENT CENTIPOISE READING
30 (Weakest)	30	18	125	89
28	20	35	100	200
26	7.5	30	35	175
24	5	70	32.5	400
22	10	200	45	975
21	5	225	40	1800
20	10	750	50	4200
18	4	700	24	4000
16	2	750	11	4000
14 (Strongest)	1	1375	5	5500

Record the deflection in degrees MacMichael and read the viscosity in centipoises from the calibration curve of the suspension used.

NOTE 1.—Before any sets of suspensions are used, they must be calibrated as noted under heading "Calibration of Suspensions."

NOTE 2.—The following table gives the diameter of the wires (new American music wire gage) used in making the suspensions and the maximum limit of torsion in degrees MacMichael to which they may be subjected before they acquire a permanent set:

SUSPENSION NUMBER (B. & S. Gage No.)	DIAMETER WIRE, IN.	TORSIONAL LIMIT, DEG. MACMICHAEL
30 (Weakest)	0.0100	125
28	0.0126	118
26	0.0159	110
24	0.0201	102
22	0.0254	92
21	0.0285	81
20	0.0320	73
18	0.0403	55
16	0.0508	35
14 (Strongest)	0.0641	5

NOTE 3.—Not all of the suspensions noted above are required in testing varnish. Suspensions 22, 21 and 20 will be sufficient for practically all varnishes. The heavier wires 18, 16 and 14 are used for very viscous materials.

CALIBRATION OF SUSPENSIONS

For the calibration of the torsion-wire suspensions used in this apparatus to measure viscosity, samples of oils verified as to absolute viscosity at 25 C. are available from the National Bureau of Standards. Sufficient number of oils to cover the range of viscosity desired should be procured. New samples should be obtained at least once a year as it has been found that the oils undergo some change on standing over long periods. The calibration of the wires is made by testing the certified samples of oils at 25 C. ± 0.2 C., following the directions as given under heading "Directions for Making Viscosity Measurement on Varnish."

The degrees MacMichael obtained for each suspension on each sample are plotted against corresponding National Bureau of Standards absolute viscosity figures (centipoise) for those samples and a line is drawn through these points. The line should be straight except possibly at low deflections where the error is correspondingly high. Once every two months the suspension should be recalibrated.

APPENDIX II

DIELECTRIC STRENGTH TESTS ON COPPER BASE

Where it is desired to make dielectric strength tests of varnish (as distinguished from the specimens prescribed in the methods, which are a combination of varnish and paper fibers), it is recommended that copper be used as the base as formerly required in the methods. The following are the directions for preparing and testing such specimens:

A 1. (*a*) Specimens shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass 8 in. square and 0.005 in. in thickness into the varnish which is at the consistency prescribed in Section 5 (*b*) of the methods.

(*b*) Each specimen shall be dipped twice, once in each direction in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish shall be dried in dust-free air after each dip at a temperature of approximately 25 C. (77 F.) for a period equal to six times the drying time recommended by the manufacturer or, in the absence of such information six times the drying time determined in accordance with Section 11 of the methods.

(*d*) Specimens of baking varnish shall be drained and then baked in dust-free air at a temperature of 105 to 110 C. (221 to 230 F.) after each dip for a period equal to three times the drying time recommended by the manufacturer or, in the absence of such information, three times the drying time determined in accordance with Section 11 of the methods.

(*e*) The final thickness of the film of varnish on each side of the specimen between 0.0018 in. and 0.002 in.

A 2. The combined dielectric strength of the two films in series shall be determined in the same manner as prescribed for the standard specimen in the methods. Ten punctures shall be made, five on each of two specimens. The thickness shall be determined as for the standard specimen except that the net thickness of the insulation obtained by subtracting the copper thickness, similarly measured, shall be used for calculating the dielectric strength.

TENTATIVE METHODS OF SAMPLE PREPARATION FOR PHYSICAL TESTING OF RUBBER PRODUCTS[1]

A.S.T.M. Designation: D 15 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1938.

Scope

1. (*a*) These general methods of testing are intended to apply to soft vulcanized rubber compounds such as are used for the lining and cover of hose and belting, for carcass and tread of tires, and for a wide variety of molded or extruded rubber products. They do not apply without modification to the testing of that material ordinarily classed as hard rubber.

(*b*) Only instructions for preparation of test specimens of rubber products and the general requirements for approved testing are included in these general methods. Standard methods for individual test procedures are provided separately or in specifications covering a particular material.

(*c*) In case of conflict between the provisions of these methods and those of the individual test procedures or specifications for a particular material, the latter shall take precedence.

Place of Test

2. Tests shall be made at the place of manufacture, unless otherwise specified. The manufacturer shall provide the requisite facilities for conducting tests, including labor and equipment.

Sampling

3. (*a*) Samples shall be obtained, if possible, from the product to be tested and in such case shall be selected in accordance with the requirements of the specifications covering the particular material.

(*b*) In case it is not practicable to obtain suitable test specimens from the finished article, the manufacturer shall, upon request, furnish pieces 6 by 6 by 0.075 in. which he guarantees to be of the same material and equivalent cure as that used in the article.

Preparing Samples of Vulcanized Rubber

4. In case samples of vulcanized rubber are to be prepared for purpose

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

These tentative methods, together with the Tentative Methods of Tension Testing of Vulcanized Rubber (D 412 - 36 T), and for Adhesion of Vulcanized Rubber (Friction Test) (D 413 - 36 T), replace the Standard Methods of Physical Testing of Rubber Products (A.S.T.M. Designation: D 15 - 32), which standard was accordingly discontinued in 1935.

of tests from the compounding ingredients, the preparation procedure[1] described in the following Paragraphs (*a*) to (*e*) shall be used:

(*a*) All ingredients shall be weighed with accuracy within 0.25 per cent of the weight specified. The final weight of the mixed batch and the sum of the weights of each ingredient shall not differ by an amount exceeding 0.6 per cent for a compounded batch or 0.3 per cent for pure gum or master batched stocks.

(*b*) Mixing of the rubber compound shall be done on a laboratory rubber mill with rolls 12 in. in width by 6 in. in outside diameter having a working distance between the guides of 10½ in. The speed of the slow roll shall be 24 r.p.m. and the gear ratio 1.4, or as near that figure as is compatible with good engineering practice. Sufficient cooling water shall be circulated through the mill rolls to maintain a roll temperature of approximately 158 F. (70 C.).

(*c*) The rubber portion of the batch shall be broken down on a warm mill with mill opening of 0.055 in. until it runs smooth. The mill then shall be adjusted to the required opening in conformity with the following table:

VOLUME OF BATCH	DISTANCE BETWEEN ROLLS
1200 cc.	0.170 in.
1100 cc.	0.160 in
1000 cc.	0.145 in.
900 cc.	0.130 in.
800 cc.	0.120 in.
700 cc.	0.110 in.
600 cc.	0.100 in.
500 cc.	0.085 in.
400 cc.	0.070 in.
300 cc.	0.055 in.

The compounding ingredients shall be next added to the rubber as rapidly as possible in the following order:

(1) Accelerators and anti-oxidants
(2) Carbon Black
(3) Fillers
(4) Softeners
(5) Sulfur

After the ingredients are all incorporated, the batch shall be cut six times alternating first from one side and then the other. This is to be interpreted as cutting two-thirds of the way across the roll and holding the rubber until the bank just disappears. After the six cuts are completed, the batch shall be cut across and rolled six times with the roll inserted endwise each time until the last when it shall be placed in the rolls lengthwise. Then, as soon as the bank is well balanced, the mill setting shall be adjusted to give a sheet approximately 0.085 in. in thickness, after cooling and the batch is cut from the rolls.

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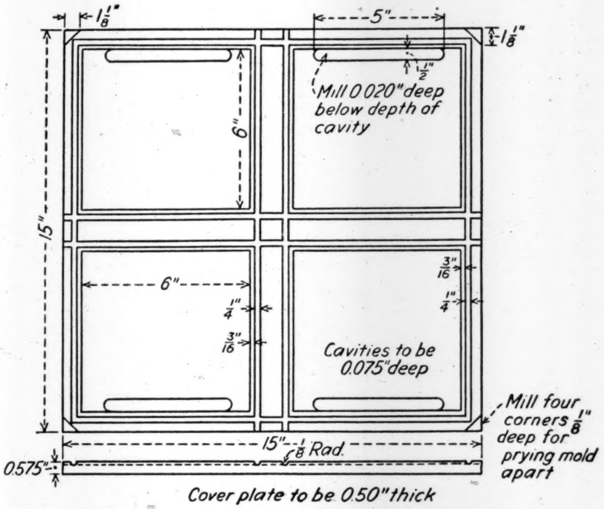
[1] This procedure is substantially in agreement with that of the Physical Testing Committee, Division of Rubber Chemistry, Am. Chemical Soc.

(*d*) The batch shall be cooled to room temperature on a flat surface and cut into slabs $\frac{1}{8}$ in. less in width and length than the corresponding dimensions of the mold cavity. Direction of grain of the rubber shall be marked on each slab. The unvulcanized stock shall be aged 18 to 24 hr. before cure.

NOTE.—It is desirable when possible that the aging be in subdued light in air having a relative humidity of 45 per cent at 82 F. (28 C.).

(*e*) The test slabs shall be vulcanized in a mold similar to that shown in Fig. 1, by being heated at a specified temperature for a given time while held under molding pressure. For this purpose a hydraulic press with heated platens is convenient. The press shall give an intensity of pressure on the mold of not less than 500 lb. per sq. in. The platens shall be of such dimensions that no portion of the slab while curing is nearer than 3 in. to the edge of the platen. In order to avoid cool spots in the platens due to condensed moisture, presses of the bored platen type are recommended. If platens of the chamber type are used, particular attention must be paid to insuring good drainage by placing the steam outlet slightly below the steam chamber. In either case, the actual platen temperatures shall be verified by means of thermocouples in the mold or other suitable temperature measuring device. The time of cure shall be that between the moment the hydraulic pressure reaches its maximum and the moment of release of the hydraulic pressure. The mold shall be brought to the curing temperature before inserting the uncured stock by being placed in


1/8"
5"
1/8"
1/2"
Mill 0.020" deep below depth of cavity
6"
15"
6"
1/4"
3/16"
3/16"
1/4"
Cavities to be 0.075" deep
Mill four corners 1/8" deep for prying mold apart
15"
1/8 Rad.
0.575"

Cover plate to be 0.50" thick

FIG. 1.—Design for Four Cavity Mold.

the closed press for a period of not less than 20 min. The minimum possible time shall elapse after the stock is placed in the hot mold until the full hydraulic pressure is applied. The slabs shall be removed from the mold immediately after the conclusion of the cure and cooled in water for 10 min. after which they shall be wiped dry and held for test.

Age of Samples

5. All tests of rubber shall be made using specimens which have aged at least 24 hr. after vulcanization. Tests of rubber made more than 60 days after vulcanization shall not be considered as evaluating the original qualities of the material.

NOTE.—Finished rubber products are not in a completely stable condition as regards physical properties. Immediately after cure, the rate of change is rapid. During the first 12 to 24 hr. the rate becomes progressively less until a minimum is reached. Very slow change continues, however, throughout the useful life of the article and is accelerated when the rubber is exposed to heat, light and air.

Condition of Samples

6. Samples and specimens for test shall not be heated, immersed in water nor subjected to any mechanical or chemical treatment prior to test except as specifically prescribed herein or in the standard test method. Any such treatment may definitely change the results of test. Particular attention is necessary to avoid previous stretching through inadvertent handling.

Temperature of Test

7. All tests of rubber shall be made at a room temperature between 70 and 90 F. (21 and 32 C.). Test specimens shall be conditioned at the test temperature for at least 30 min. just prior to test. The actual test temperature shall be recorded in all cases. Close comparisons should not be made between test results obtained under temperature conditions differing by more than 10 F. (5.5 C.).

Separation of Rubber

8. (*a*) When the tests to be made require prior separation of rubber from cotton fabric or other material, the separation shall be performed without the use of gasoline, if possible, and without rupture or excessive stretching. To avoid unnecessary stretching, it is desirable to cut the material into strips slightly wider than a test specimen. The separation shall be made gradually and a little at a time while the rubber is gripped near the point of separation.

(*b*) If it is necessary to employ gasoline to effect the separation, it shall be straight-run gasoline of the quality known as aviation grade and shall have the following characteristics. After use of gasoline, the rubber shall be placed so as to permit free evaporation from all parts of its surface and shall be allowed to rest at least 1 hr. before being tested.

Specific gravity at 60 F.	0.685 to 0.705
Distillation limits:	
Initial boiling point	100 to 120 F.
10 per cent evaporated	128 to 143 F.
20 per cent evaporated	140 to 155 F.
30 per cent evaporated	150 to 164 F.
40 per cent evaporated	156 to 174 F.
50 per cent evaporated	164 to 184 F.
60 per cent evaporated	173 to 194 F.
70 per cent evaporated	182 to 207 F.
80 per cent evaporated	193 to 223 F.
90 per cent evaporated	209 to 245 F.
95 per cent evaporated	224 to 260 F.
Dry	250 to 286 F.
Recovery, min	97 per cent

The gasoline shall contain no lead compounds and shall not leave an appreciable amount of oily residue when evaporated.

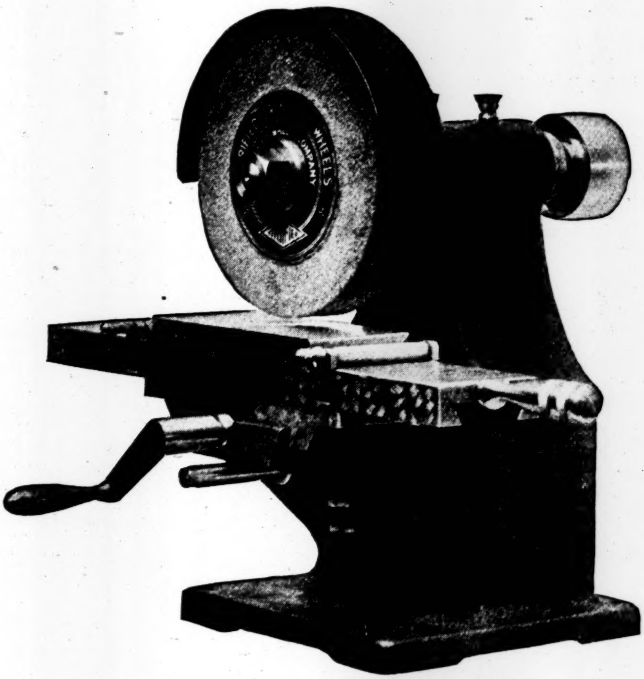


FIG. 2.—Grinder for Buffing Samples.

Buffing

9. Samples of rubber shall not be buffed, except when necessary, to remove unevenness of surface such as fabric impressions or corrugations which would interfere with an accurate measurement of thickness or when necessary to reduce the thickness to the amount prescribed for test specimens in specific test methods. If required, buffing shall be done by means of a suitable grinding machine and without causing excessive heating of the rubber. It is recommended that a grinder similar to that shown in Fig. 2 be used. The grinder shall have an abrasive wheel of about No. 30

grit, 5 in. in diameter revolving at a speed of 2500 to 3500 r.p.m., and shall be provided with a slow feed in order that very little rubber may be removed at one cut avoiding overheating. When removing fabric impressions or other unevenness, buffing shall not be carried beyond the point at which the unevenness in gage just disappears. When necessary to reduce the thickness of the sample for preparation of test specimens, it may be desirable to slice the rubber nearly to the required thickness and finish by buffing. In any case, the final buffed surfaces shall be finished as smoothly as possible. At least 30 min. shall elapse between the buffing and testing of the specimens.

NOTE.—Specimens with buffed surfaces instead of mold finish usually give slightly lower tensile strength test results because of the tendency for surface roughness to favor premature breaking of the specimens.

Test Methods

10. All tests of rubber parts shall be carried out in accordance with the requirements of the A.S.T.M. standard specification for the material or the A.S.T.M. standard test method for determining the specific physical property required.

Retests

11. Any lot represented by a sample which fails in one or more tests may be retested. For this purpose two additional samples shall be selected. Failure of either in any respect shall be cause for rejection.

TENTATIVE METHODS FOR TESTING FLAT RUBBER BELTING[1]

A.S.T.M. Designation: D 378 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1933; ADOPTED, 1936; REVISED AND REISSUED AS TENTATIVE, 1938.

Scope

1. (*a*) These methods cover the test procedure recommended for evaluating the physical properties of the flat type of rubber belting which contains cotton duck reinforcement. The term "rubber" as herein used includes synthetic compounds as well as compounds of natural rubber. Such belting includes the types used for transmission of power or conveying and elevating material, and is classified as follows:

(*1*) *Friction Surface Belt.*—Possessing no distinct rubber cover other than that resulting from rubber frictioning process.

(*2*) *Rubber Covered Belt.*—Possessing a distinct rubber cover extending over the outside and around the edges of the belt.

(*3*) *Fabric Surface Belt.*—Possessing at least one face of plain uncoated duck.

(*b*) Except as otherwise specified in these methods for rubber belting, the following methods of test of the American Society for Testing Materials applicable in general to vulcanized rubber shall be complied with as required and are hereby made a part of these methods:

General Physical Test Requirements.—Tentative Methods of Sample Preparation for Physical Testing of Rubber Products (A.S.T.M. Designation: D 15 – 38 T)[2]

Tension Test.—Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 – 36 T).[3]

Adhesion Test.—Tentative Methods of Test for Adhesion of Vulcanized Rubber (Friction Test) (A.S.T.M. Designation: D 413 – 36 T).[3]

(*c*) In case of conflict between the provisions of these methods and those of detailed specifications or methods of test for a particular belt, the latter shall take precedence.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

These methods are in effect a revision of, and are intended to replace the Standard Methods of Testing Rubber Belting Used for Power Transmission (D 378 – 36), 1936 Book of A.S.T.M. Standards, Part II, p. 1274

[2] See p. 1099.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, pp. 1105, 1120 (1936); also 1938 Book of A.S.T.M. Tentative Standards, pp. 1287, 1307.

SAMPLING

Sampling

2. (*a*) Samples selected for the purpose of tests shall be the full width and thickness of the belt and shall be of sufficient length to perform the desired tests. In general, the amount of sample required shall be as shown in Paragraph (*b*). The frequency of sampling for each size and type shall be one sample from each lot of 2000 ft. of belt, or fraction thereof.

(*b*) The following lengths of samples are recommended:

WIDTH OF BELT, IN.	LENGTH OF SAMPLE WHEN TENSION TEST IS REQUIRED, IN.	LENGTH OF SAMPLE WHEN TENSION TEST IS NOT REQUIRED, IN.
Under 8	32	12
8 to 18	26	8
Over 18	22	6

DIMENSIONAL MEASUREMENTS

Measurements of Dimensions

3. (*a*) *Width.*—The width shall be determined by laying across the belt a steel rule or tape graduated to sixteenths of an inch. The width shall be recorded in inches and fractions thereof to the nearest $\frac{1}{16}$ in.

(*b*) *Length.*—In determining the length of a belt the measurement shall be made with a steel tape. The reference marks shall be parallel and in the same plane. In determining the length of an endless belt the measurement shall be made on the inside surface using three or more reference marks.

(*c*) *Thickness of Belts and Covers.*—The thickness of the belts and covers shall be determined by means of a micrometer graduated to thousandths of an inch, and having a presser foot 0.25 ± 0.01 in. in diameter exerting a pressure of 9 ± 0.1 oz. on the test specimen. The pressure shall be applied by means of a weight.

(*d*) *Thickness of Covers.*—The thickness of the top or bottom cover shall be the minimum thickness found on the test specimen prepared for the adhesion test and shall be determined as follows: The over-all thickness of the test specimen shall first be measured. The rubber cover shall then be stripped from one surface and the thickness of the carcass, including the remaining cover, shall be measured. The difference between the first and second measurements will represent the thickness of the cover removed. The same procedure shall be followed on the test specimen from which the first cover has been removed, when the thickness of the other cover is required.

(*e*) *Thickness of Cover when Tie Cloth is Used.*—The thickness of the cover shall include the tie cloth.

TEST CONDITIONS AND NUMBER OF TESTS

Test Conditions

4. (*a*) Tests shall be made within a temperature range of 70 to 90 F. (21 to 32 C.). The samples shall be kept at a temperature between these limits for at least 30 min. previous to the time of testing. The values obtained in determining the physical properties under these methods will differ, depending upon the age of the samples; therefore, the test shall be made within a definite time limit which shall not exceed 60 days from receipt of the material by the purchaser.

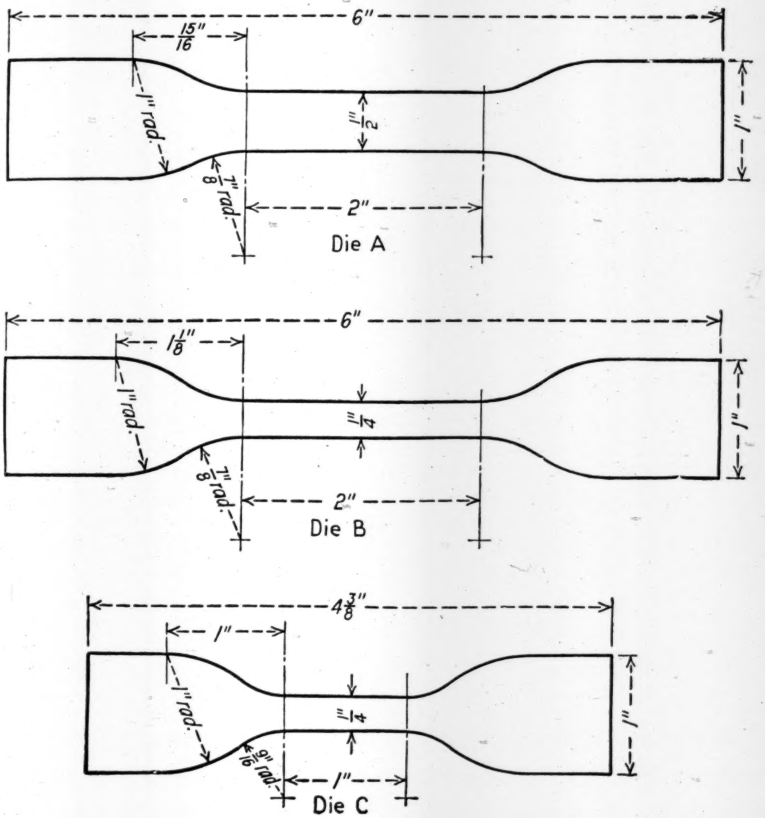

FIG. 1.—Tensile Strength and Elongation Test Specimens.

Die B shall be used when the size of the sample and the tension and stretch limits of the testing machine permit, with exceptions as explained below. If the tension limit is too low for the machine, use Die A. If the stretch is too high for the machine, use **Die C.** Die C shall also be used for samples which are too small for A or B.

Number of Tests

5. (*a*) When minimum requirements are established, one specimen shall be tested for each physical characteristic required in the detailed specifications for a particular belt. If the results do not meet the specified

requirements, two additional specimens shall be prepared from the original sample and tested. Should the results of either of these tests be below the specified requirements, the material represented by the sample shall be considered to have failed to meet the specifications.

(*b*) If minimum requirements are not established, at least three specimens shall be tested and the results averaged.

TENSION TESTS OF RUBBER PARTS

Apparatus

6. (*a*) *Testing Machine.*—Tensile strength and elongation tests shall be made on apparatus accurate to within plus or minus 1 per cent and provided with an accurate device for indicating the actual maximum load at rupture. The preferred type of apparatus is a power-driven machine of the inclination balance or pendulum type, but a spring balance, accurately calibrated, may be used.

(*b*) *Grips for Testing.*—The grips for holding the test specimen shall be such that they tighten automatically, exerting a uniform pressure, proportional to the applied tension, across the full width of the enlarged end of the test specimen. The moving grip shall move at a constant speed of 20 in. per min.

Test Specimen

7. (*a*) Tests for tensile strength and ultimate elongation shall be made only on rubber covers from which standard dumbbell specimens at least $\frac{3}{64}$ in. in thickness can be prepared.

(*b*) The rubber parts to be tested shall be separated from the rest of the belt without the use of gasoline, if possible. If it is necessary to employ gasoline to effect the separation, it shall be straight-run gasoline of the quality known as aviation grade and shall have the characteristics listed in the following table:

Specific gravity at 60 F. (15.6 C.)	0.685 to 0.705
Distillation limits:	
Initial boiling point	100 to 120 F.
10 per cent evaporated	128 to 143 F.
20 per cent evaporated	140 to 155 F.
30 per cent evaporated	150 to 164 F.
40 per cent evaporated	156 to 174 F.
50 per cent evaporated	164 to 184 F.
60 per cent evaporated	173 to 194 F.
70 per cent evaporated	182 to 207 F.
80 per cent evaporated	193 to 223 F.
90 per cent evaporated	209 to 245 F.
95 per cent evaporated	224 to 260 F.
Dry	250 to 286 F.
Recovery, min	97 per cent

The gasoline shall contain no lead compounds and shall not leave an appreciable amount of oily residue when evaporated.

After use of gasoline, the test specimen shall be allowed to rest, with frequent turning to permit free evaporation from all parts of its surface, at least 1 hr. before being tested.

(*c*) *Preparation of Test Specimen.*—The test specimen shall be stamped out from the separated cover with a steel die constructed substantially in accordance with Figs. 1 *A*, *B*, or *C*. The dies shall be kept sharp and free from nicks to avoid leaving ragged edges on the rubber. Cutting may be facilitated by wetting the rubber surface and cutting edges of the die. The rubber shall be rested on a smooth, slightly yielding surface which will not injure the blade. Care shall be taken that the cut edges are perpendicular to the other surfaces of the specimen and have a minimum of concavity.

(*d*) *Buffing.*—The specimen shall be buffed only to the extent necessary to remove surface corrugations, irregularities, or excess thickness and to insure smooth faces. Buffing shall be done without excessive heating and the test specimen shall be allowed to rest after buffing for at least 10 min. before being tested.

(*e*) *Marking.*—Parallel gage lines 1 to 2 in. apart, depending upon the die used, shall be marked on the test specimen at right angles to the longitudinal axis by means of an accurate stamp or bench marker. Care shall be taken to make fine lines and to avoid injuring the specimen.

(*f*) *Measurement of Test Specimen.*—The thickness of the test specimen shall be the minimum thickness found between the marks on the constricted portion, using the standard micrometer described in Section 3 (*c*). The minimum thickness and width between the gage marks shall be taken in calculating the area to be used in determining the tensile strength of the specimen.

(*g*) *Number of Test Specimens.*—Three specimens per sample shall be tested for determinations of tensile strength, elongation, and stress-strain properties, except as noted in Section 5 (*a*). Results on specimens which break outside of the straight reduced section or which are found to be imperfect shall be discarded and retests shall be made. In case the ultimate tensile strengths fail to check within 5 per cent of the highest value obtained, additional specimens shall be tested until two or more such check results are obtained. The final values shall be the averages of the check tests, discarding the determinations on specimens which are outside of the above limits.

Procedure

8. (*a*) The test specimen shall be placed in the jaws. The jaws shall be separated at the specified rate of speed until rupture takes place. The distance between the centers of the gage marks noted at the instant of rupture shall be measured, using a rule or tape graduated to eighths of an inch or smaller divisions.

(*b*) The tensile strength in pounds per square inch shall be calculated from the breaking load indicated by the machine and the original cross-sectional dimensions of the test specimen.

(*c*) The elongation shall be the difference between the original gage length and the total distance between the gage marks at the time of rupture as measured in Paragraph (*a*) and shall be expressed as a percentage of the original gage length.

ADHESION TESTS

Test Specimen

9. The adhesion test specimens shall be prepared by accurately cutting a strip 1 in. in width longitudinally of the test sample from belts under 8 in. in width, and transversely from belts 8 in. and over in width, using a sharp tool which will leave clean-cut edges. The test specimen shall be at least 6 in. in length. The various plies shall be separated at one end of the test specimen a sufficient distance to permit attaching the jaws of the testing clamp.

Procedure

10. (*a*) The adhesion between plies shall be determined by the dead weight method, that is, through the application of a specified or known weight on successive plies of a specimen 1 in. in width in such a manner as to cause separation. Adhesion shall be expressed numerically as the average rate of separation in inches per minute.

(*b*) The test specimen shall be suspended by the separated end, all plies of which except the one under test shall be clamped in the jaws of the testing clamp. A minimum weight sufficient to maintain the test specimen in approximately a vertical position shall be attached to its lower end. The first ply shall have the specified weight attached to the separated end with suitable provision for supporting and releasing it slowly without jerking. A mark shall be placed on the line of separation at the beginning and at the end of the test. After the weight is removed at the end of the test, the distance between the marks shall be measured. The rate of separation shall be determined by observing the duration of the test with a stop-watch or a watch having a second hand, and by measuring, after the weight has been removed, the length stripped between the marks placed at the beginning and end of the test on the portion other than that stripped. Under these conditions the rate of separation shall not exceed 1 in. per min.

(*c*) The test shall be continued on the successive plies by releasing the separated end of each from the stationary clamp and reattaching the specified weight. This procedure shall be followed until two plies only remain within the grip of the stationary clamp. No tests shall be made between the last two plies of the test specimen (Note). When tests are desired on these plies, a second specimen shall be prepared and shall be tested, starting from the opposite side in accordance with the procedure described in Paragraphs (*a*) and (*b*).

NOTE.—The last two plies are omitted from the test because sufficient rigidity cannot be maintained at the point of separation to obtain the approximate condition of separation in a vertical plane.

(*d*) The adhesion between the rubber covers and the body of the belt shall be determined on the test specimen prepared for ply adhesion. The procedure shall be the same as that described for ply adhesion in Paragraphs (*a*) and (*b*).

(*e*) On rubber-covered belting constructed with a tie cloth or breaker fabric between the outside ply and cover, the adhesion between the body of the belt and covering including the tie cloth, or between the tie cloth and adjacent rubber cover shall be determined on separate test specimens in accordance with the procedure described in Paragraph (*b*).

BEADING TEST[1]

Procedure

11. The beading in all friction-surface belting 4 in. in width or over shall be tested as follows: A 4-in. transverse section of belting shall be taken and beginning on the seamless side, the plies shall be removed until three plies only remain intact. A line shall be drawn down the middle of the beading and then on each side of this line, and $\frac{5}{8}$ in. distant from it, two parallel lines shall be scribed. The section shall be inserted in a vise so that the jaws grip the specimen coincident with the two outer lines. The vise shall be tightened until the inner surfaces of the doubled specimens just touch at the top of the vise, and the specimen shall be held in this position for 10 min. Under this test the beading shall not crack or loosen in the seam.

TENSION TEST OF BELTING

Apparatus

12. (*a*) The specimens shall be tested in a suitable vertical testing machine equipped with wedge-shaped jaws. The base of the jaws shall be at right angles to the longitudinal center of the test specimen when correctly placed in the jaws. The base surfaces of the two edges of each set of jaws shall be in the same horizontal plane and adequate means shall be provided to lock the two halves of the jaws so that they will travel together in parallelism. Means shall be provided to hold the jaws in convenient position for correctly inserting the test specimen as well as to loosen them after each test. The heads of the testing machine shall be constructed to provide rigid support for the jaws. The inner surfaces of the wedge-shaped slots shall be machined to within 0.005 in. of a true

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[1] The beading is considered by many rubber technologists as having no relation to the service value of belting, except for some specialized requirement. The beading test is, therefore, not recommended for general use.

plane. The included angle of the two sides shall be from 17.5 to 22 deg. and this angle must be identical with that of the jaws.

Test Specimen

13. For belting up to 5 in. in width, inclusive, a longitudinal tension test specimen 20 in. in length and the full width of the belt shall be cut from the test sample. For belting between 5 and 6 in. in width, $\frac{1}{2}$ in. shall be removed from each edge. For belting 6 in. and over in width the test specimen shall be 20 in. in length and 5 in. in width, and the edges of the specimen shall be cut parallel to and at least $\frac{1}{2}$ in. from the edges of the belt. The thickness of the test specimen shall not exceed 4 plies. Excess plies shall be removed by stripping, removing them alternately from each face. When testing rubber-covered belts, rubber covers $\frac{3}{64}$ in. and over in thickness shall be stripped from the test specimen.

Procedure

14. (*a*) *Tensile Strength.*—The grooves and gripping surfaces of the jaws shall be cleaned and the edge surfaces and backs shall be well lubricated and kept free of any foreign matter. Slippage may be prevented by the use of coarse emery cloth which shall be inserted between the corrugations of the jaws and the test specimen, with the rough side toward the specimen, and this cloth shall be renewed frequently. Great care must be used to prevent the loose particles of grit which fall from the emery cloth from lodging upon any of the pressure surfaces during the test. The test specimen shall be tested in the machine described in Section 12. Care shall be taken to place the specimen squarely in the jaws of the machine. The jaws shall be 12 in. apart when the test specimen is inserted and the rate of separation shall be between $\frac{3}{4}$ and 2 in. per min., inclusive. If the specimen breaks in the jaws the results shall be discarded and the test shall be repeated. From the breaking strength thus determined, the tensile strength of the belt per inch of width per ply shall be calculated and reported.

(*b*) *Elongation.*—The elongation, when required, shall be taken during the performance of the tensile strength test. For this purpose, parallel reference lines 8 in. apart shall be marked across the middle of the test specimen at right angles to the longitudinal axis. The elongation shall be determined by means of a steel scale or suitable extensometer. When an extensometer is used, it shall be pinned or held on the specimen with the points on the 8-in. reference lines and the scale set at zero. The load shall then be applied at the specified rate of speed and the elongation at the breaking point shall be noted.

(*c*) *Stress-Strain.*—If the stress-strain characteristics of the belt are desired they may be obtained simultaneously with the tensile strength determination. In this case, elongation readings of the steel scale or extensometer shall be taken at intermediate points. The total load on the belt and the percentage elongation for each increment increase in load per inch per ply shall be reported as well as the total load and percentage elongation at failure.

INSPECTION AND REJECTION

Inspection

15. (*a*) All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. The manufacturer shall afford the inspector, without charge, all reasonable facilities to test and inspect the belting.

(*b*) The purchaser may make the tests and inspection to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests and inspection shall be made at the expense of the purchaser, not later than 60 days after receipt of the material.

Retests and Rejection

16. (*a*) Any material which fails in one or more tests may be resampled and retested at the expense of the manufacturer. For this purpose two additional samples shall be selected from the belt for the test which failed to meet the requirements. Failure of either of the retested samples shall be cause for final rejection.

(*b*) Rejected material shall be disposed of as directed by the manufacturer and at his expense.

TENTATIVE METHODS OF TESTING RUBBER HOSE[1]

A.S.T.M. Designation: D 380 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. (*a*) These methods are intended for use in the examination and test of all types and constructions of rubber hose. The term "rubber" as herein used includes synthetic compounds as well as compounds of natural rubber.

(*b*) Except as otherwise specified in these methods for rubber hose, the following methods of test of the American Society for Testing Materials, applicable in general to vulcanized rubber, shall be complied with as required and are hereby made a part of these methods:

General Physical Test Requirements.—Tentative Methods of Sample Preparation for Physical Testing of Rubber Products (A.S.T.M. Designation: D 15 - 38 T).[2]

Tension Test.—Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 - 36 T).[3]

Aging Test.—Tentative Methods of Test for Accelerated Aging of Vulcanized Rubber (A.S.T.M. Designation: D 428 - 36 T).[3]

Adhesion Test.—Tentative Methods of Test for Adhesion of Vulcanized Rubber (Friction Test) (A.S.T.M. Designation: D 413 - 36 T).[3]

(*c*) In case of conflict between the provisions of these methods and those of detailed specifications or methods of test for a particular hose, the latter shall take precedence.

SAMPLING

Sampling

2. (*a*) A sample of sufficient length for proper performance of the required tests shall be cut from the hose when possible without impairing its use and the pieces of hose from which samples have thus been cut shall be accepted by the purchaser as full length, provided the hose meets the specified requirements. In general, the amount required and the frequency of sampling for each size and type of hose shall be one 30-in. sample from

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] See p. 1099.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, pp. 1105, 1113, 1120 (1936); also 1938 Book of A.S.T.M. Tentative Standards, pp. 1287, 1295, 1307.

each 500 ft., or fraction thereof, of hose over 1¼ in. in nominal diameter and one 36-in. sample from each 500 ft., or fraction thereof, of hose 1¼ in. or under in nominal diameter.

(*b*) Where the construction of the hose does not permit the cutting of samples as described in Paragraph (*a*) without impairment of use, as in wire inserted hose, dredging sleeves, etc., a separate length having the same specifications shall be provided, either as an additional length or as a prolongation built on to the hose. Wire shall be omitted from the prolongation or sample length unless the detailed physical tests include requirements that measure the effect of the wire or metal elements in the construction. Additional lengths taken for purpose of tests shall be paid for by the purchaser, provided they conform to the specified requirements.

(*c*) The sampling of cotton-jacketed rubber-lined hose shall be in accordance with detailed specifications for this material.

MEASUREMENTS OF SIZE AND THICKNESS

Measurement of Hose

3. (*a*) *Length.*—The length shall be determined by means of a steel tape or calibrated measuring device and shall not include the length of fittings except when specifically so requested and recorded. In the case of cotton-jacketed rubber-lined hose, the length shall be determined under a 10-lb. internal pressure.

(*b*) *Outside Diameter.*—The outside diameter shall be determined by calculation from measurement of the outside circumference. A tape graduated to read the diameter directly may be used.

(*c*) *Inside Diameter.*—The inside diameter shall be measured with a plug gage except that on hose larger than 3 in. in nominal diameter, a steel scale or caliper may be used.

Thickness of Tube, Cover or Other Rubber Elements

4. (*a*) The thickness of a rubber element from any type of hose except cotton rubber-lined fire hose shall be determined by means of a standard micrometer graduated to thousandths of an inch and having a presser foot 0.25 ± 0.01 in. in diameter, exerting under dead-weight load a total force of 9 ± 0.1 oz. In the case of cotton rubber-lined fire hose, a spring gage micrometer provided with a presser foot 0.375 ± 0.01 in. in diameter, exerting a total force of 2.1 oz. (60 g. ± 0.1 oz.) shall be used.

(*b*) A rubber element adjoining a braid or helical wound reinforcing member of any material shall have the thickness taken as the average between two measurements of thickness, one of which shall be obtained using the unbuffed specimen and the other using a specimen which is buffed just sufficiently to remove the braid or helical corrugations.

(*c*) A rubber element adjoining a seamless woven jacket of any material shall have the thickness taken on a specimen which is buffed just sufficiently to remove the corrugations caused by the woven jacket. Where backing is used on a rubber element, the backing shall be removed before thickness measurements are taken.

(*d*) A rubber element adjoining flexible metal convoluted lining shall have the thickness determined at the valleys formed by the tops of the metal convolutions. The opposite side of the rubber element, adjacent to other reinforcing members, shall be prepared for thickness measurement as specified in the other paragraphs of this section, depending upon the type of reinforcing member.

(*e*) A rubber element adjoining reinforcing fabric woven prior to assembly in the hose, shall have the thickness determined on a specimen which is unbuffed.

TEST CONDITIONS AND NUMBER OF TESTS

Test Conditions

5. The temperature of the testing room shall be between 70 and 90 F. (21 and 32 C.). The samples to be tested shall be kept in this room for at least 30 min. previous to the time of testing.

Number of Tests

6. (*a*) When minimum requirements are established, one specimen shall be tested for each physical characteristic required in the detailed specifications for a particular hose except in the immersion tests given in Sections 20 to 23, inclusive. If the results do not meet the specified requirements, two additional specimens shall be prepared from the original sample and tested. Should the results of either of these tests be below the specified requirements, the sample shall be considered to have failed to meet the specifications.

(*b*) If minimum requirements are not established, at least three specimens shall be tested and the results averaged.

TENSILE STRENGTH AND ELONGATION OF RUBBER

Tension Test Apparatus

7. (*a*) *Testing Machine.*—Tensile strength and elongation tests shall be made on apparatus accurate within ± 1 per cent and provided with an accurate device for indicating the actual maximum load at rupture. The preferred type of apparatus is a power-driven machine of the inclination-balance or pendulum type, but a spring balance accurately calibrated may be used.

(*b*) *Grips for Testing.*—The grips for holding the test specimen shall be such that they tighten automatically, exerting a uniform pressure, proportional to the applied tension, across the full width of the enlarged end of the test specimen. The moving grip shall move at a constant speed of 20 in. per min.

Tension Test Specimen

8. (*a*) *Separation of Rubber Parts.*—Sufficient length shall be cut from the hose sample to provide longitudinal tension test specimens from hose 1¼ in. and under in nominal diameter and transverse test specimens on larger sizes. The rubber parts to be tested shall be separated from the balance of the hose without the use of gasoline, if possible. If it is necessary to employ gasoline to effect the separation, it shall be straight run gasoline of the quality known as aviation grade and shall have the following characteristics:

Specific gravity at 60 F	0.685 to 0.705
Distillation limits:	
Initial boiling point	100 to 120 F.
10 per cent evaporated	128 to 143 F.
20 per cent evaporated	140 to 155 F.
30 per cent evaporated	150 to 164 F.
40 per cent evaporated	156 to 174 F.
50 per cent evaporated	164 to 184 F.
60 per cent evaporated	173 to 194 F.
70 per cent evaporated	182 to 207 F.
80 per cent evaporated	193 to 223 F.
90 per cent evaporated	209 to 245 F.
95 per cent evaporated	224 to 260 F.
Dry	250 to 286 F.
Recovery, min.	97 per cent

The gasoline shall contain no lead compounds and shall not leave an appreciable amount of oily residue when evaporated.

After use of gasoline, the test specimen shall be allowed to rest at least 1 hr. before being tested.

(*b*) *Preparation of Specimen.*—The test specimen shall be stamped out from the separated rubber part with dies conforming to Fig. 1 *A*, *B*, or *C*. In no case shall the thickness of the test specimens exceed ⅛ in. Test specimens shall be free from marked irregularities of thickness.

(*c*) *Buffing.*—The specimen shall be buffed, but only to the extent necessary to remove surface corrugations, irregularities, or excess thickness, and to insure smooth faces. Buffing shall be done without excessive heating and the test specimen shall be allowed to rest after buffing for at least 10 min. before being tested.

(*d*) *Marking.*—Parallel gage lines 1 to 2 in. apart, depending upon the die used, shall be marked on the test specimen at right angles to the longitudinal axis by means of an accurate stamp or bench marker. Care must be taken to make fine lines and to avoid injuring the specimen.

(*e*) *Measurement of Test Specimen.*—The thickness of the test specimen shall be the minimum thickness found between the marks on the constricted portion, using the standard micrometer described in Section 4 (*a*).

Tension Test Procedure

9. (*a*) The test specimen shall be placed in the jaws. The jaws shall be separated at the specified rate of speed until rupture takes place. The

distance between the centers of the gage marks noted at the instant of rupture shall be measured using a rule or tape graduated to eighths of an inch or smaller divisions.

(*b*) Test specimens that break outside of the gage marks or are found to be imperfect shall be discarded and retests shall be made.

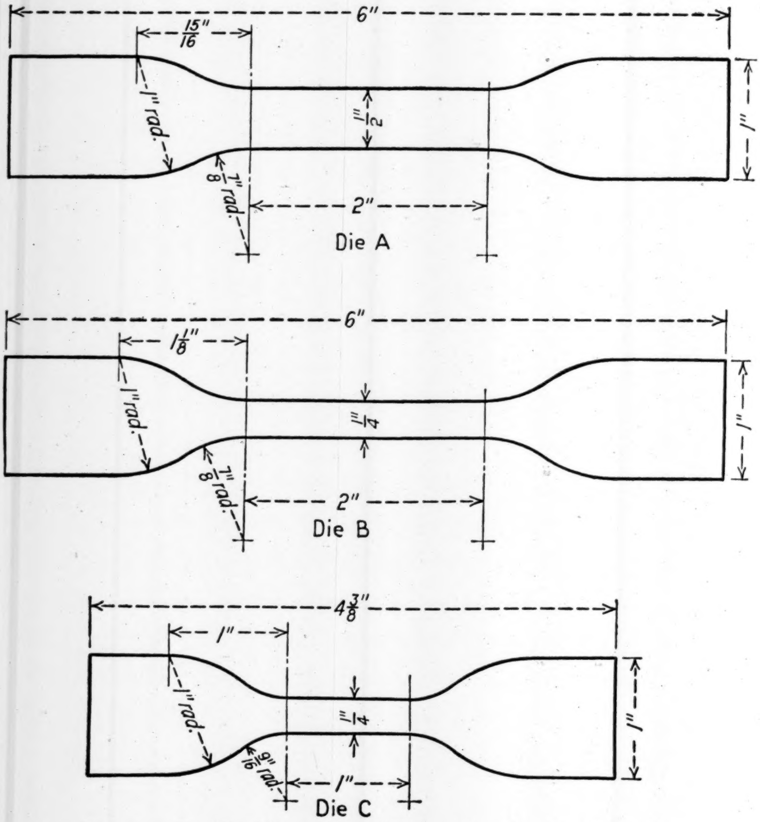

FIG. 1.—Tensile Strength and Elongation Test Specimens.

Die B shall be used when the size of the sample and the tension and stretch limits of the testing machine permit, with exceptions as explained below. If the tension limit is too low for the machine, use Die A. If the stretch is too high for the machine, use Die C. Die C shall also be used for samples which are too small for A or B.

(*c*) The tensile strength in pounds per square inch shall be calculated from the breaking load indicated by the machine and the original cross-sectional dimensions of the test specimen.

(*d*) The elongation shall be the difference between the original gage length and the total distance between the gage marks at the time of rupture as measured in Paragraph (*a*) and shall be expressed in percentage of the original gage length.

PERMANENT SET[1]

Permanent Set Test

10. The specimen for the permanent set test shall be prepared as for determining tensile strength (Section 8) and placed in a suitable stretching device. The grips shall conform to the requirements specified in Section 7 (*b*). The specimen shall be stretched to an amount equal to three-fourths of the ultimate elongation specified, held for 2 min., released, and the distance between the centers of the gage marks measured at the expiration of 2 min. The difference between this measurement and the original gage length divided by the original gage length and expressed as a percentage shall be recorded as the permanent set. If no ultimate elongation is specified, the specimen shall be stretched an amount equal to three-fourths of the elongation determined under Section 9.

ADHESION TESTS

Adhesion Test Specimens

11. (*a*) From cotton-jacketed rubber-lined hose adhesion test specimens shall be cut transversely from the samples in rings 2 in. in width. These rings shall then be opened at the lap and laid out flat so as to give rectangular specimens of length equal to the full circumference of the hose. On each specimen a central strip of lining 1½ in. in width shall be cut accurately, the cut extending through the lining but not entirely through the cotton jacket. These strips shall be separated from the jacket at one end for a distance of about 1½ in.

(*b*) From other types of hose the adhesion test specimens shall be cut transversely from the samples in rings 1 in. in width using a sharp tool which will leave clean edges. On hose ¼ to 4 in., inclusive, in internal diameter the specimens shall be tested in ring form and shall be referred to as "ring specimens." For hose over 4 in. in internal diameter the rings shall be cut through at the point where the outside ply of fabric ends, and opened to form strips which shall be referred to as "strip specimens."

(*c*) Adhesion specimens from hose less than ¼ in. in internal diameter shall be cut longitudinally from the hose. Since the width of these specimens will be less than 1 in., the adhesion shall be determined on the contact width of the test specimen.

(*d*) In hose constructions having braided wire or woven wire filler reinforcing members, it is impracticable to prepare adhesion test specimens except for determining cover adhesion.

Adhesion Test Procedure

12. (*a*) *Ring Specimens.*—The ring specimen shall be placed on a mandrel having a diameter equal to the nominal diameter of the hose.

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[1] The amount of permanent set is considered by many rubber technologists as having no relation to the service value of rubber compounds except for some specialized requirements. The permanent set test is, therefore, not recommended for general use.

The parts to be tested shall be separated sufficiently by hand to permit attaching the jaws of a testing clamp. With the mandrel supported so that it may revolve freely with minimum friction, the prescribed weight shall be attached to the clamp with suitable provision for supporting and releasing it slowly without jerking. The average rate of separation shall not exceed 1 in. per min. The separation shall be noted for a period of 4 min., unless the small size of the specimen makes a shorter period necessary.

(*b*) *Strip Specimens.*—The various parts to be tested shall be separated at one end of the strip specimen a sufficient distance to permit attaching the jaws of the testing clamp. The strip specimen shall be suspended by the separated end, all separate parts of which, except the one under test, shall be clamped in the jaws of the testing clamp. A minimum weight sufficient to maintain the strip specimen in approximately a vertical position shall be attached to the lower end of the test specimen, or the specimen may be held against a vertical plate in such a manner as to hold the specimen in approximately a vertical position during the test. The specified weight shall be applied to the separated end with suitable provision for releasing it slowly without jerking. The average rate of separation shall not exceed 1 in per min. The separation shall be noted for a period of 4 min.

HYDROSTATIC TESTS

Types of Tests

13. Hydrostatic tests of hose consist of subjecting the specimen to the action of internal water pressure under specified conditions to determine either the bursting strength of the hose or the effect of lower hydrostatic pressures in producing changes similar to those occurring in service. In the latter case, the test may be used as an inspection proof test with a minimum safe limit. Bursting strength is determined on short specimens cut from the full hose lengths but in tests for service effects and for proof inspection, the full lengths are used as specimens. The specimens may be tested, as required, in straight, curved or kinked positions, depending upon the stresses which are desired to be evaluated.

Application of Hydrostatic Pressure

14. Hydrostatic pressure shall be applied by means of a hand or power-driven hydraulic pump or an accumulator system. The hose shall be connected to the water line or pump and filled with water prior to application of pressure, allowing all air in the hose to escape through a petcock provided for the purpose. This is important as a safety measure because expansion of air compressed in the hose, when suddenly released by bursting or other failure, might result in a serious accident. The petcock shall then be closed and the pressure shall be applied at a uniform rate of increase of approximately 1000 lb. per sq. in. per min. Pressure shall be measured with a calibrated gage.

Bursting Test

15. (*a*) The specimen for the hydrostatic test for bursting strength shall be at least 18 in. in length for hose 3 in. and smaller in inside diameter, and at least 24 in. in length for larger hose. The pressure shall be raised as specified in Section 14 until failure, and the pressure at which failure occurs shall be considered the bursting strength of the hose.

(*b*) The curved bursting strength test for cotton rubber-lined fire hose shall be made in accordance with Paragraph (*a*), except that the hose shall be firmly secured at both ends to a suitable test frame which is curved to a radius of 27 in.

Hydrostatic Pressure Tests

16. (*a*) When tests for elongation, contraction, twist, warp rise, and expansion are required, the hose shall be stretched out straight for inspection, and a pressure of 10 lb. per sq. in. applied. All original observations and measurements shall be taken at this pressure. The designated test pressure shall be applied at the rate specified in Section 14 without releasing the original pressure of 10 lb. per sq. in. and final measurements taken. The test pressure shall not be applied longer than 5 sec.

(*b*) *Proof Pressure Tests.*—When proof pressure tests to determine leakage of hose or couplings are required, the proof pressure shall be applied as in Section 14, and held 1 min. The proof pressure shall not exceed 40 per cent of the specified minimum bursting strength.

(*c*) *Kink Tests.*—When kink tests are required, each length of hose selected shall be filled with water with the petcock open to allow all air to escape. The petcock shall then be closed and the hose shall be kinked at one end 18 in. from the coupling by tying the coupling back against the hose so that there will be a sharp kink. The pressure shall then be raised as specified in Section 14 to the required pressure and immediately released.

STEAM TESTS

Types of Test

17. (*a*) Steam tests of hose consist of subjecting test specimens having previously determined physical properties to the action of steam under controlled conditions for known periods after which the physical properties are again measured and the changes noted. In these methods two types of test are given which differ in the manner in which the specimens are exposed to the action of the steam. In one type, named the rack method, the steam is in contact only with the interior of the hose while in the other type, called the digester method, the specimen is entirely surrounded by steam. The choice of type of test to be used for a given hose sample depends on the kind of service being evaluated.

(*b*) Tensile strength and ultimate elongation of the rubber parts and strength of adhesion are the physical properties used in addition to visual and manual inspection for evaluating the effect of the steam. These shall be determined in accordance with Sections 6 to 11, inclusive.

Rack Method

18. (*a*) *Apparatus.*—Two fixed horizontal steam headers having suitable connections for attaching specimens shall be placed one above the other at such distance that the specimens will just fit between the connections in a vertical position without distortion. Dry saturated steam at the required pressure shall be supplied to the specimens through the upper header which shall be equipped with a pressure regulating valve, a recording gage and suitable indicating gages. The lower header shall be connected to a steam trap. Shutoff valves shall be provided at each opening in each header.

(*b*) *Test Specimen.*—The test specimen shall be a piece of the hose sample cut to length as required by the apparatus except that the length shall not be less than 16 in. nor more than 24 in.

(*c*) *Procedure.*—For determining the physical properties before steaming, a portion of the hose sample not required for the rack test shall be used. The specimen for steaming shall be mounted in the apparatus and subjected to internal steam pressure of 75 ± 2 lb. per sq. in. for 7 hr. on each of two successive days, the steam being turned off and the hose allowed to cool during the 17-hr. intermediate interval. After the second steaming period, the hose shall be removed from the apparatus, allowed to cool and held under laboratory atmospheric conditions for not less than 12 hr. nor more than 48 hr. after which the physical properties after steaming shall be determined.

Digester Method

19. (*a*) *Apparatus.*—For the digester test, a suitable pressure vessel having a steam inlet with a regulating valve and a condensate outlet through a steam trap shall be provided. The vessel shall have a petcock air vent for escape of trapped air at the beginning of the test and shall be equipped with a recording thermometer or pressure gage. A perforated metal or wire frame shall be provided for holding the specimens at least 6 in. above the condensate outlet.

(*b*) *Test Specimen.*—The test specimen shall be a piece of the hose sample cut to such length that all test specimens for physical properties can be obtained after discarding at least 2 in. at each end.

(*c*) *Procedure.*—For determining the physical properties before steaming, a portion of the hose sample not required for the digester test shall be used. The specimen for steaming shall be placed in the digester and surrounded by dry saturated steam at a pressure of 45 ± 3 lb. per sq. in. for 48 hr. continuously. At the conclusion of this period, the pressure in the digester shall be released, the hose removed and examination made at once for blistering of the inner tube or cover or loosening of the tube from the fabric. The specimen shall be allowed to cool and to rest under laboratory atmospheric conditions not less than 12 hr. nor more than 48 hr. after which the physical properties after steaming shall be determined.

IMMERSION TESTS FOR SWELL AND DETERIORATION OF HOSE USED FOR PETROLEUM PRODUCTS

Types of Test

20. Immersion tests for evaluating the swelling and deteriorating effects of petroleum products on rubber hose consist of subjecting suitable test specimens from the rubber portion having known physical properties to the action of selected solvents by immersing the specimens completely in solvent under controlled conditions for definite periods after which the physical properties are again determined and the changes noted. In these methods two types of test are given. One type involves measurement of the change in volume of the rubber caused by the swelling action of the solvent. In the other type, the change in strength is measured. For the latter, alternative methods using different solvents are given. In any of the immersion tests, the choice of method and solvent depends upon the nature of the actual service and the petroleum product which is there being used.

Gasoline Immersion Swelling Test

21. (*a*) *Test Specimens.*—The test specimens shall be rectangular rubber blocks 2 by 1 in. having a thickness not over $\frac{1}{16}$ in. They shall be cut from the hose and buffed on both faces only to the extent necessary to insure smoothly buffed faces, except when the material is too thick, in which case the buffing shall be sufficient to reduce the specimens to $\frac{1}{16}$ in. Three specimens shall be used for each test and the results averaged.

(*b*) *Procedure.*—The volume of each test specimen shall be measured by the water displacement method in which the specimen is accurately weighed to the nearest milligram in air (W_1) and in distilled water (W_2) at room temperature. When weighing in water, care must be taken that the specimen is free from adhering air bubbles and, if necessary, it may first be wetted by being dipped in 95 per cent ethyl alcohol and thoroughly rinsed with distilled water. After weighing, the specimen shall be blotted dry with filter paper, completely immersed in gasoline and allowed to stand for 24 hr. at room temperature. The gasoline used shall be straight run aviation grade as described in Section 8 (*a*). Excessive evaporation may be avoided by fitting the container loosely with a cork stopper. At the termination of the immersion period, the specimen shall be removed from the gasoline, dipped in 95 per cent ethyl alcohol, blotted lightly with filter paper and immediately weighed in distilled water (W_3) as before. The final weighing shall be completed within 5 min. after removal from gasoline.

(*c*) *Calculation.*—The volume increase shall be calculated as follows:

$$\text{Percentage Increase in Volume} = \frac{W_2 - W_3}{W_1 - W_2} \times 100$$

Kerosine-Benzol Immersion Strength Deterioration Test

22. (*a*) *Test Specimens.*—Six dumbbell-shaped test specimens, prepared as described in Section 8, will be required. Both faces of the dumbbells shall be buffed.

(*b*) *Apparatus.*—The apparatus in which a specimen is subjected to the action of the solvent shall consist of a glass container fitted tightly with a cork stopper and an efficient reflux condenser. The specimen shall be supported at least $\frac{1}{2}$ in. from the bottom of the tube by means of a wire screen or similar device.

(*c*) *Kerosine.*—The kerosine shall be of a grade conforming to the following requirements:

TEST	A.S.T.M. DESIGNATION[a]	LIMIT
Burning quality test, hr	D 187	16 min.
Flash point, deg. Fahr	D 56	115 min.
End point, deg. Cent	D 86	330 max.
Cloud point, deg Fahr	D 97	5 max.
Sulfur, per cent	D 90	0.13 max.
Color, Saybolt number	D 156	+16 min.

[a] These designations refer to the following methods of the American Society for Testing Materials:
Standard Method of Test for Burning Quality of Kerosine Oils (A.S.T.M. Designation: D 187),[1]
Standard Method of Test for Flash Point by Means of the Tag Closed Tester (A.S.T.M. Designation: D 56),[2]
Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86),[3]
Standard Method of Test for Cloud and Pour Points (A.S.T.M. Designation: D 97),[4]
Tentative Method of Test for Sulfur in Petroleum Oils by Lamp Method (A.S.T.M. Designation: D 90 - 34 T),[5] and
Standard Method of Test for Color of Refined Petroleum Oil by Means of the Saybolt Chromometer (A.S.T.M. Designation: D 156).[6]

(*d*) *Benzol.*—The benzol shall be a pure, water white grade, free from suspended matter and conforming to the following requirements:

Specific gravity at 60 F	0.875 to 0.886
Distillation limits:	
Initial boiling point	168 to 172 F.
95 per cent evaporated	174 F., max.
Dry	176 F., max.
Recovery	98 per cent, min.

(*e*) *Procedure.*—Three specimens shall be tested for tensile strength and elongation in accordance with Section 9 and the results averaged to give the properties of the rubber before immersion. The remaining three specimens shall be placed in the immersion apparatus and completely surrounded by solvent consisting of 85 per cent kerosine and 15 per cent benzol. With the reflux condenser in place the apparatus containing the specimen shall then be maintained at a temperature of 135 to 140 F. (57 to 60 C.) for 48 hr. Use of a thermostatically controlled liquid bath is recommended. At the end of this period, the specimens shall be removed, dipped once in acetone at room temperature and blotted lightly with filter paper. The specimens shall then be suspended or placed on a screen and allowed to dry at room temperature in air protected from drafts for 24 hr. after which the tensile strength and elongation after immersion shall be determined as before, except that the measurements for cross-sectional area and test length between bench marks shall be taken after immersion and drying. The deterioration shown by the difference between the determinations before and after immersion shall be expressed as a percentage of the original property.

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 834.
[2] *Ibid.*, p. 907.
[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 137.
[4] 1936 Book of A.S.T.M. Standards, Part II, p. 853.
[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 911 (1934); also 1938 Book of A.S.T.M. Tentative Standards, p. 815.
[6] 1938 Supplement to Book of A.S.T.M. Standards, p. 134.

Oil Immersion Strength Deterioration Test

23. This determination shall be made exactly as in the case of the kerosine-benzol test described in Section 22, except that the temperature during immersion shall be maintained at 200 F. ± 2 F. (93 C. ± 1 C.) for 48 hr. and the solvent shall be a neutral, pale, paraffin-base oil. The oil shall be yellow in color with blue fluorescence, free from turbidity and shall conform to the following requirements:

TEST	A.S.T.M. DESIGNATION[a]	MINIMUM	MAXIMUM
Specific gravity, per cent	.....	0.878	0.882
Flash point, deg. Fahr	D 92	330	340
Saybolt Universal Viscosity at 122 F., sec.	D 88	61	66

[a] These designations refer to the following methods of the American Society for Testing Materials:
Standard Method of Test for Flash and Fire Points by Means of Open Cup (A.S.T.M. Designation: D 92),[1]
Standard Method of Test for Viscosity by Means of the Saybolt Viscosimeter (A.S.T.M. Designation: D 88).[2]

INSPECTION AND REJECTION

Inspection

24. (*a*) All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified. The manufacturer shall afford the inspector, without charge, all reasonable facilities to test and inspect the hose.

(*b*) The purchaser may make the tests and inspection to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests and inspection shall be made at the expense of the purchaser not later than 60 days after receipt of the material.

Retests and Rejection

25. (*a*) Any material which fails in one or more tests may be resampled and retested at the expense of the manufacturer. For this purpose two

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[1] 1936 Book of A.S.T.M. Standards, Part II, p. 892.
[2] 1938 Supplement to Book of A.S.T.M. Standards, p. 148.

additional samples shall be selected from the hose for this test which failed to meet the requirements. Failure of either of the retested samples shall be cause for final rejection.

(*b*) Rejected material shall be disposed of as directed by the manufacturer and at his expense.

TENTATIVE METHODS OF TESTING RUBBER INSULATED WIRE AND CABLE[1]

A.S.T.M. Designation: D 470 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1937; Revised, 1938.

Scope

1. These methods are intended for use in testing all types of rubber-insulated wire and cable. They are not to be considered completely applicable to all types of wire and cable, nor do they necessarily include every test applicable to a particular type. To determine the tests to be made on a particular wire or cable, reference should be made to the specifications for that type.

Physical Tests of Insulation

Scope

2. Physical tests include the determination of tensile strength, tensile stress, ultimate elongation, permanent set, and accelerated aging.

Sampling

3. (*a*) *Number of Samples.*—Wire and cable shall be sampled as follows:

For sizes less than 250,000 cir. mils, one sample shall be selected for each quantity ordered between 2000 ft. and 50,000 ft. of wire or cable and one additional sample for each additional 50,000 ft. thereafter. No sample shall be selected from lots of less than 2000 ft.

For sizes 250,000 cir. mils and over, one sample shall be selected for each quantity ordered between 1000 ft. and 25,000 ft. of wire or cable and one additional sample for each additional 25,000 ft. thereafter. No sample shall be selected from lots of less than 1000 ft.

(*b*) *Size of Samples.*—Samples shall be at least 6 ft. in length where the wire size is less than 250,000 cir. mils, and at least 3 ft. in length where the wire size is 250,000 cir. mils or over.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

Test Specimens

4. (*a*) *Number.*—From each of the samples selected in accordance with Section 3, test specimens shall be prepared as follows:

		NUMBER OF TEST SPECIMENS
For determination of initial properties (unaged).....	Tensile strength, tensile stress, and ultimate elongation..	3
	Permanent set..	3
For aging tests..........	Air pressure heat or oxygen pressure..................	3
	Air oven..	3

One specimen of each three shall be tested and the other two held as spares except that where only one sample is selected all three specimens shall be tested and the average of the results reported.

(*b*) *Size.*—In the case of wire and cable smaller than No. 6 A.w.g. with an insulation thickness less than $\frac{3}{32}$ in., the test specimen may be the entire section of the insulation. Where the full cross-section is used, the sample shall not be cut longitudinally. In the case of wire and cable of No. 6 A.w.g. and larger, or in the case of wire and cable smaller than No. 6 A.w.g. having an insulation thickness greater than $\frac{3}{32}$ in., samples approximately square in section, with a cross-section not greater than 0.025 sq. in., shall be cut from the insulation. In extreme cases, it may be necessary to use a segmented or sector-shaped specimen. The test specimens shall be approximately 6 in. in length.

(*c*) *Preparation.*—The test specimen shall have no surface incisions and be as free as possible from other imperfections. Surface irregularities, such as corrugations due to stranding, etc., shall be removed by buffing. When a test specimen is buffed, care shall be taken to make it smooth and of uniform thickness.

NOTE.—The removal of the rubber insulation can be greatly accelerated and in most cases a test specimen which is an entire section can be obtained free from surface incisions and imperfections by means of mercury. The mercury should be introduced at one end of the sample between the insulation and the tinned surface of the conductor, and the sample inclined on a support with the end to which the mercury is applied at the top. The separation of the rubber insulation results from the amalgamation of the tin of the conductor with the mercury. The amalgamation is assisted by first immersing and rubbing the tinning on the exposed end of the conductor in the mercury.

(*d*) *Condition and Age.*—Samples of the insulated wire or cable for physical and accelerated aging tests shall be taken after vulcanization and prior to the application of any covering except that a cable tape may be applied before vulcanizing. No tests shall be made within 24 hr. nor later than 60 days after vulcanization unless agreed to by the manufacturer. Specimens shall not be heated, immersed in water, or subjected to any mechanical or chemical treatment not specifically prescribed in these specifications. Specimens for accelerated aging tests having cable tape applied prior to vulcanization shall be aged with such tape removed.

Calculation of Area

5. Calculation of the area of the test specimens shall be made as follows:

(*a*) Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the area of the conductor. The area of a stranded conductor shall be calculated from its maximum diameter.

(*b*) Where a slice cut from the insulation by a knife held tangent to the wire is used, and the slice so cut has the cross-section of a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. (The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.)

(*c*) Where the cross-section of the slice is not a segment of a circle, the area shall be calculated from a direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

(*d*) Where a portion of a sector of a circle has to be taken where the conductor is large and the insulation thin, the area shall be calculated as the thickness times the width. (This applies either to a straight test piece or one stamped out with a die, and assumes that corrugations have been removed by buffing.)

(*e*) Where a portion of a sector of a circle has to be taken where the conductor is large and the insulation thick, the area shall be calculated as the proportional part of the area of the total cross-section.

(*f*) The dimensions of specimens to be aged shall be determined before the aging cycle is begun.

Physical Test Procedures

6. (*a*) Except as otherwise specified in these methods, the physical properties shall be determined in accordance with the Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 – 36 T) of the American Society for Testing Materials.[1]

(*b*) The samples to be tested shall be at a temperature of 20 to 28 C.

(*c*) For all physical tests, specimens shall be marked with gage marks 2 in. apart and placed in the jaws of the testing machine with a maximum distance between jaws of 4 in.

(*d*) Tensile stress shall be determined as that load per unit area which produces the elongation of the sample required by the specifications.

(*e*) The set test shall be made on a separate test specimen having a length of not less than 6 in. and marked with gage marks 2 in. apart. The specimen shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. and shall be stretched at the rate of 20 in. per min. (jaw speed) until the gage marks are 6 in. apart. The test specimen shall then be released within 5 sec. and the distance between gage marks shall be determined 1 min. after the beginning of release. The set is the difference between this length and the original 2-in. gage length.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1105 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1287.

Aging Tests

7. (*a*) Except as otherwise specified in these methods, samples shall be aged in accordance with the Tentative Methods of Test for Accelerated Aging of Vulcanized Rubber (A.S.T.M. Designation: D 428 – 36 T)[1] and the Tentative Method for Air Pressure Heat Test for Vulcanized Rubber (A.S.T.M. Designation: D 454 – 37 T)[2] of the American Society for Testing Materials.

(*b*) The period of aging shall be as stated in the specifications.

(*c*) In not less than 16 hr. nor more than 48 hr. after the completion of the aging process, the aged samples shall be subjected to tensile strength and ultimate elongation tests in accordance with Section 6. Physical tests on both aged and unaged specimens shall be made at the same time.

Retests

8. If any specimen fails to meet the values which may be specified for any test, either before or after aging, that test shall be repeated on two additional specimens from the same sample.

Report

9. The report shall include the following:

(*a*) The calculated values of tensile strength, tensile stress, ultimate elongation, and set,

(*b*) All observed and recorded data on which the calculations are based,

(*c*) The date of vulcanization of the rubber, if known,

(*d*) The dates of all tests,

(*e*) The ambient temperatures during the period of physical testing,

(*f*) The type of testing machine used,

(*g*) The method of aging, and

(*h*) The time of aging.

ELECTRICAL TESTS OF INSULATION

Scope

10. Voltage tests include the following:

A. Voltage Test on Entire Cable

B. Double-Voltage Test on Short Samples

C. Cold-Bend, Long-Time Voltage Test on Short Samples

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 36, Part I, p. 1113 (1936); also 1938 Book of A.S.T.M. Tentative Standards, p. 1295.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1122 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1302.

Apparatus

11. (*a*) Tests shall be made with alternating current, except when direct current is specified.

(*b*) For tests with a-c. voltage, there shall be used a transformer of such capacity that the crest factor (ratio of maximum to mean effective) of the test voltage shall not differ by more than plus or minus 10 per cent from that of a sinusoidal wave when the transformer is loaded with the test specimen. Voltage shall be measured by a tertiary coil and voltmeter or by an electrostatic voltmeter or potential transformer with suitable low voltage indicator, connected to the secondary, or high voltage side, of the test transformer. The frequency of the test voltage shall be nominally between 25 and 60 cycles per second, inclusive.

(*c*) For tests with d-c. voltage, there shall be used a battery, generator or suitable rectifying equipment supplied with alternating current. Voltage shall be measured with an electrostatic voltmeter, or in the case of the rectifying equipment, with suitable low voltage indicators, provided the latter are so connected that their indications are independent of the test load. The test rectifier shall at all times be so loaded, if necessary by the used of additional capacitive ballast, that the d-c. ripple does not exceed 4 per cent.

Application of Voltage

12. (*a*) *Single Conductor Cables.*—Single conductor cables shall be tested between conductor and metallic sheath or water in which they are immersed.

(*b*) *Multiple Conductor Cables.*—In the case of multiple conductor cables, each conductor shall be tested against adjacent conductors and against the sheath or water.

Rate of Application

13. Voltage shall be increased from zero to the prescribed test value at a uniform rate of rise approximating but not exceeding 3 kv. per sec.

A. Voltage Test on Entire Cable

14. Wire and cable shall be subjected to a-c. voltage as specified. When d-c. is specified, the d-c. voltage shall be 2.2 times the required a-c. voltage. The duration of test shall be 5 min.

15. Tests shall be made as follows:

(*a*) ***General.***—Where insulated conductors are subjected to a high voltage test in water they shall be immersed in a grounded water bath and tested while still immersed.

(*b*) *Single Conductor.*—Single conductors shall be tested after 12-hr. immersion and without covering except a tape or braid applied before vulcanization.

Rubber sheathed conductors shall be immersed and tested after the sheath is applied.

Where a metallic sheath is applied, the conductors shall be retested against the sheath.

(*c*) *Multiple Conductor.*—The individual conductors of multiple conductor cables shall be tested before assembling as prescribed in Paragraph (*b*).

After assembly, each conductor shall be tested against the adjacent conductors. Where a metallic sheath is applied each conductor adjacent to the sheath shall, in addition, be tested against the sheath.

Cables having a rubber or other non-metallic waterproof sheath shall be immersed for 12 hr. and the conductors tested against ground. Cables covered with cable tape and braid or double braid with a weather-resistant finish shall not be immersed for testing.

Cables having a metallic armor shall be tested after the application of the armor at a voltage equal to 80 per cent of the test voltage before armoring. Such cables shall be immersed for 12 hr. prior to test only if for submarine use, and if no lead sheath or shielding is applied.

B. Double-Voltage Test on Short Samples

Sampling

16. One sample, 10 ft. or more in length as may be required, shall be taken from each 10,000 ft. or fraction thereof of each type of cable, with a minimum of three samples. Tests upon lots of less than 10,000 ft. shall be made only when specifically requested in the purchase order. Samples may be taken either from process or from completed cable, at the option of the manufacturer.

Procedure

17. At least one-half of the total length of each test specimen shall be in contact with the grounded terminal during the period of test. This part of each specimen shall be immersed in water at room temperature, after the removal of any metallic coverings, for a period of 1 hr. prior to testing. At the end of this time, each test specimen shall be subjected for 5 min. to a voltage equal to twice that specified in Section 14.

C. Cold-Bend, Long-Time Voltage Test on Short Samples

Sampling

18. One 10-ft. sample shall be taken from each 10,000 ft. or fraction thereof of completed cable. Tests upon lots of less than 10,000 ft. shall be made only when specifically requested in the purchase order.

Procedure

19. (*a*) Each sample shall be subjected to a temperature of −10 C. for a period of 2 hr. Immediately at the end of this period, the sample

shall be bent 180 deg. around a cylindrical mandrel and then straightened. It shall then be bent 180 deg. around the mandrel in the opposite direction. The cable shall be so held during bending operations that it cannot revolve around its own axis.

(*b*) The diameter of the mandrel shall be determined by the following table:

THICKNESS OF CONDUCTOR INSULATION, SIXTY-FOURTHS OF AN INCH	MANDREL DIAMETER AS A MULTIPLE OF OVER-ALL CABLE DIAMETER: UP TO 500,000 CIR. MILS	500,000 CIR. MILS AND OVER
10 to 12	8	10
13 to 20	10	12
21 and over	12	12

(*c*) Immediately following the bending test, the cable, while still bent, shall be subjected to the test voltage specified in Section 14 for a period of 2 hr.

Report

20. The report shall include the following:

(*a*) The type of test,
(*b*) The time and place of test,
(*c*) The test voltages,
(*d*) The duration of each test, and
(*e*) The result of each test, including location of any failure.

Insulation Resistance Tests

Apparatus

21. (*a*) The apparatus shall consist of a source of constant potential of from 100 to 500 v., a galvanometer with suitable shunts, and a calibrating resistance of at least 0.1 megohm.

(*b*) The galvanometer should have a high current sensitivity. A sensitivity of the order of 10^{-9} amp. per cm. with scale at a meter distance is desirable. The most convenient shunt is the type known as a universal shunt whereby the current through the galvanometer may be changed by powers of ten without changing its damping.

Insulation Resistance Test Procedure

22. (*a*) Single conductor cables shall be tested between conductors and sheath or water in which they are immersed. Tests on multiple conductor cables with unshielded conductors shall be made between each conductor and all other conductors and the sheath or water. Tests on multiple conductor cables with shielded conductors shall be made between each conductor and shield. The conductor of the wire or cable shall be connected to the negative terminal, and the sheath and other conductors, if any, to the positive terminal of the apparatus. On short sections of wire or cable, a guard circuit should be used to prevent end leakage.

(*b*) The deflection of the galvanometer caused by passing current through the calibrating resistance shall first be determined. The wire or cable shall then be connected into the circuit. At the end of 1 min. after closing the circuit, the galvanometer deflection shall again be noted, and the temperature of the wire or cable observed.

Calculations

23. Insulation resistance is commonly expressed in terms of a standard length. The insulation resistance of a standard length may be determined from the following formula:

$$R = M \frac{D}{d} \frac{S}{s} \frac{l}{l_s}$$

where M = the calibrating resistance,
D = the deflection produced with calibrating resistance in circuit,
S = the shunt ratio with calibrating resistance in circuit,
d = the deflection produced with test specimen in circuit,
s = the shunt ratio with test specimen in circuit,
l = the length of entire wire or cable, and
l_s = the standard length.

Temperature Correction

24. The insulation resistance of wires and cables varies widely with temperature. If the temperature at which the measurement was made differs from 60 F. (15.6 C.), the resistance shall be reduced to that at 60 F. (15.6 C.) by multiplying the measured value by the temperature coefficient specified for the insulation in question.

Moisture Absorption Test

Moisture Absorption Test Procedure

25. (*a*) A 15-ft. sample of the insulated wire or cable shall be taken after vulcanization and prior to the application of any coverings except tape applied before vulcanizing. Such cable tape shall be removed before making the moisture absorption test. The middle 10 ft. of the sample shall be immersed in distilled water for a period of 14 days with the $2\frac{1}{2}$-ft. portion at each end kept above the water as leakage insulation. The specific inductive capacity of the insulation shall be taken after 1, 7, and 14 days with the water at the same temperature for each measurement. The water shall be maintained at room temperature but not less than 70 F. (21 C.).

(*b*) *Calculations.*—The specific inductive capacity shall be determined at commercial frequencies and shall be calculated as follows:

$$\text{Specific inductive capacity} = 13{,}600\ C \log_{10} \frac{D}{d}$$

where C = the capacity in microfarads of 10 ft. of sample,
D = the diameter over the insulation, and
d = the diameter over the conductor.

The moisture absorption test shall be made only when requested by the purchaser.

Ozone Resistance Test

Scope

26. This method is intended for use in testing rubber insulation for high voltage use, the surface of which may be exposed to attack by ozone.

Special Solutions Required

27. (*a*) *Starch Indicator Solution.*—Stir 1 g. of soluble starch into 40 ml. of cold water, heat to boiling, while stirring constantly, until starch is thoroughly dissolved, dilute with cold water to about 200 ml. and add 2 g. of crystallized zinc chloride. Let solution settle for some time and pour off for use the supernatant liquid. Renew every 2 or 3 days.

A fresh solution of 1 g. of soluble starch in 100 ml. of boiling water may also be used.

When using these starch solutions as an indicator, add a few drops of acetic acid (10 per cent) to the solution being titrated.

(*b*) *Standard Iodine Solution.*—Place in a weighing tube 2 g. of KI and 10 ml. of water, and weigh the tube and solution. Add iodine directly to the solution in the weighing tube on the balance pan until the total iodine in solution is about 0.1 g. Accurately weigh the solution with the added iodine. Determine the amount of iodine added to the solution. Remove the weighing tube, pour the solution into a beaker, wash the weighing tube held over the beaker with distilled water, pour solution from the beaker into a volumetric flask, rinse the beaker into a 1000-ml. volumetric flask with distilled water, and dilute the solution in the flask to 1 liter. This solution is fairly stable if kept in a cool, dark place in a well-stoppered, brown bottle.

(*c*) *Sodium Thiosulfate Solution.*—Prepare a $Na_2S_2O_3$ solution of approximately the same strength as the standard iodine solution by placing about 0.24 g. of $Na_2S_2O_3 \cdot 5H_2O$ in a 1000-ml. volumetric flask and dilute to 1 liter. Since this solution gradually loses its strength, standardize it against the standard iodine solution on the day tests are run. The method for calculating the strength of the $Na_2S_2O_3$ solution is described in Section 32 (*a*).

(*d*) *Potassium Iodide Solution.*—Dissolve about 20 g. of pure KI in 2 liters of water.

(*e*) *Acetic Acid* (*10 per cent*).

Apparatus

28. (*a*) The apparatus shall consist of (*1*) a device for generating a controlled amount of ozone, (*2*) a means for circulating ozonized air, under

controlled condition of humidity and temperature through a chamber containing the specimens to be tested, and (*3*) a means for the determinating the percentage of ozone concentration.

(*b*) A convenient form of apparatus is shown in Fig. 1. Air flows from an air pump, or compressed air supply through a series of chambers as indicated. The acid drier consists of two 500-ml. gas washing bottles filled to 30 per cent of capacity with concentrated H_2SO_4 (sp. gr. 1.84). In series with this is a second acid drier containing anhydrous calcium chloride or anhydrous calcium sulfate, and a U-tube hygrometer containing a small quantity of anhydrous copper sulfate which is used as an indicator of moisture. The temperature is regulated by the control bath. The thermometer indicates the temperature of the outgoing air. The calibrated flow meter indicates the rate of air travel. The air is partly ozonized in the generator which consists of a pair of concentric electrodes separated by a thin glass dielectric between which voltage in controlled amount may be applied. This generator may be conveniently supplied by a potential transformer of from 20 to 30-kv. rating. Ozonized air passes directly to the bottom of the test chamber. This contains a filter consisting of a layer of loose mineral wool held between two perforated grills. Discharge in the test chamber is accomplished by a double cock arrangement, one acting as a direct discharge into the outside atmosphere and the other, when normally closed, acting as a by-passing test cock. The manometer indicates the pressure in the test chamber. A test chamber 15 by 15 by 20 in., having a test compartment of 15 by 15 by 15 in. above the top grill of the filter, will accommodate all samples where the over-all bent diameter of the sample does not exceed 20 in.

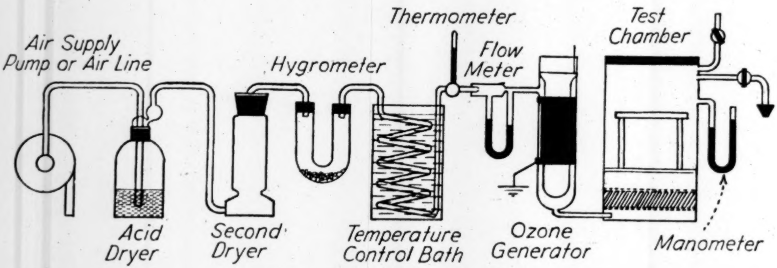

Fig. 1.—Apparatus for Determination of Ozone Resistance.

NOTE.—If the acid in the first acid dryer should carry over into the second acid dryer a scrubber bottle may be inserted between the two dryer bottles.

Test Specimens

29. (*a*) Specimens for the ozone test shall be selected at a point not less than 10 ft. from the end of the test coil. All tapes and outer coverings shall be removed, except in the case where a processing tape is applied

directly over the compound for the purpose of vulcanization, in which case this tape need not be removed.

(*b*) Two specimens shall be taken for this test. One specimen shall be bent around the mandrel and through the specified angle in accordance with Paragraphs (*c*) or (*d*). The other specimen shall be similarly bent but in the reverse direction.

(*c*) Specimens less than 1 in. in diameter shall be bent, at room temperature, through an angle of 360 deg., without twisting, around a mandrel, the diameter of which shall be not less than three and one-half nor more than four and one-half times the outside diameter of the sample. The two ends of each sample shall be tightly clamped to the mandrel to prevent any movement of the bent section during test.

(*d*) Samples 1 in. and larger in diameter shall be bent, at room temperature, through an angle of 180 deg., without twisting, around a mandrel, the diameter of which shall be not less than five and one-half nor more than six and one-half times the outside diameter of the sample.

(*e*) Samples shall not be heated, immersed in water, or subjected to any mechanical or chemical treatment not specifically prescribed in these methods. Samples at room temperature shall be placed in the ozone testing chamber in not less than 30 nor more than 45 min. after bending.

Procedure

30. The air shall be circulated through the test apparatus at a constant rate of flow for at least 15 min. prior to bending of the specimens. The flow shall be between 10 and 20 cu. ft. per hr. as indicated on the flow meter. The manometer shall indicate a slight pressure above atmospheric in the test chamber. This pressure may be controlled by the degree of closure of the discharge cock. After the ozone has been generated for a few minutes, a check shall be made on the percentage of ozone concentration (Section 31). The voltage of the ozone generator shall then be regulated so as to give a concentration of ozone of not less than 0.010 per cent nor more than 0.015 per cent by volume. The temperature of the air leaving the control bath shall be regulated to 25 ± 5 C. When constant test conditions are obtained the test specimens shall be inserted in the test chamber and allowed to remain for a period of 1 hr.

Determination of Ozone Concentration

31. (*a*) *Collection of Sample.*—Fill a 400-ml. separatory funnel with KI solution (1 per cent) and attach to the test cock. Simultaneously open the test cock and the stopcock on the separatory funnel until about 200 ml. of the KI solution is drained into a graduate. Quickly close the test cock and stopcock, remove and stopper the separatory funnel which now contains about a 200-ml. sample of the gas to be analyzed. Shake the separatory funnel to produce complete reaction of the KI solution.

(*b*) *Analysis of Sample.*—Titrate the solution in the separatory funnel with the standardized sodium thiosulfate solution, using a starch indicator.

Calculations

32. (*a*) *Sodium Thiosulfate Solution.*—Standardize the $Na_2S_2O_3$ solution in accordance with the following formula:

$$E = \frac{F \times C}{S}$$

where E = the iodine equivalence of $Na_2S_2O_3$ expressed as milligrams of iodine per milliliter of $Na_2S_2O_3$,
F = the number of milliliters of the iodine solution,
C = the concentration of iodine in milligrams per milliliter, and
S = the number of milliliters of $Na_2S_2O_3$ used to titrate the solution.

(*b*) *Ozone.*—Since 1 mg. of iodine is equivalent to 0.1 ml. of ozone at room temperature and pressure (within the accuracy of this method of analysis at average room temperature and pressure); the ozone may be calculated as follows:

$$O = E \times 0.1$$

where O = the number of milliliters of ozone at room temperature and pressure equivalent to 1 ml. of $Na_2S_2O_3$ solution used, and
E = the iodine equivalent of $Na_2S_2O_3$ expressed as milligrams of iodine per milliliter of $Na_2S_2O_3$.

then:

$$\text{Percentage of ozone} = \frac{S \times O}{M} \times 100$$

where S = the number of milliliters of $Na_2S_2O_3$ used to titrate the solution,
O = the number of milliliters of ozone at room temperature and pressure equivalent to 1 ml. of $Na_2S_2O_3$ solution used, and
M = the number of milliliters of the sample collected.

Tentative Method of Test for
RESISTANCE TO LIGHT CHECKING AND CRACKING OF RUBBER COMPOUNDS[1]

A.S.T.M. Designation: D 518 - 38 T

Issued, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for use in estimating the comparative ability of soft rubber compounds to withstand the effect of sunlight and weather. It does not apply to the testing of material ordinarily classed as hard rubber.

Note.—This method is not suited for use in purchase specifications both because correlation with service life is uncertain and because the results from duplicate specimens tested in different locations do not check. No relation between the results of the test and actual service performance is given or implied. The test is principally of value when used for comparisons between two or more rubber compounds.

Type of Test

2. This test consists of continuously exposing rubber specimens held under strain in direct natural sunlight and weather for definite periods and observing their deterioration as evidenced by the appearance and growth of minute cracks or crazing on the surfaces. The progressive deterioration may ultimately result in rupture of the specimens.

Method A. Exposure of Straight Specimens

Apparatus

3. The apparatus shall consist of the following:

(*a*) *Mounting Block.*—A rectangular wooden block for supporting the extended specimens. The block shall be 5.5 in. in width and approximately 15 in. in length and shall have a thickness of not less than $\frac{7}{8}$ in. The block shall have the grain running lengthwise and shall be suitably reinforced on the back to prevent warping. Both of the 15-in. edges of the face carrying the specimens shall be rounded with a $\frac{1}{8}$-in. radius. (Fig. 1 shows the details of construction). The block shall be planed smooth and painted with two coats of du Pont clear lacquer or its equivalent.

(*b*) *Tacks.*—Aluminum tacks, size No. 6, made from Alloy No. 51-S for fastening the specimens to the edges of the wooden block.

(*c*) *Angle Strips.*—Right-angled aluminum molding strips $\frac{1}{2}$ in. by $\frac{7}{8}$ in. of approximately No. 22 gage for shielding the specimens where tacked and bent over the edges of the block. Strips made from commercial aluminum sheet of Alloy No. 2-S are suitable.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

Test Specimens

4. (*a*) The test specimens shall be rectangular strips 1 in. in width by 6 in. in length cut longitudinally from standard laboratory test slabs having a thickness of 0.075 in. minimum and not to exceed 0.100 in.

(*b*) Duplicate specimens shall be tested whenever possible.

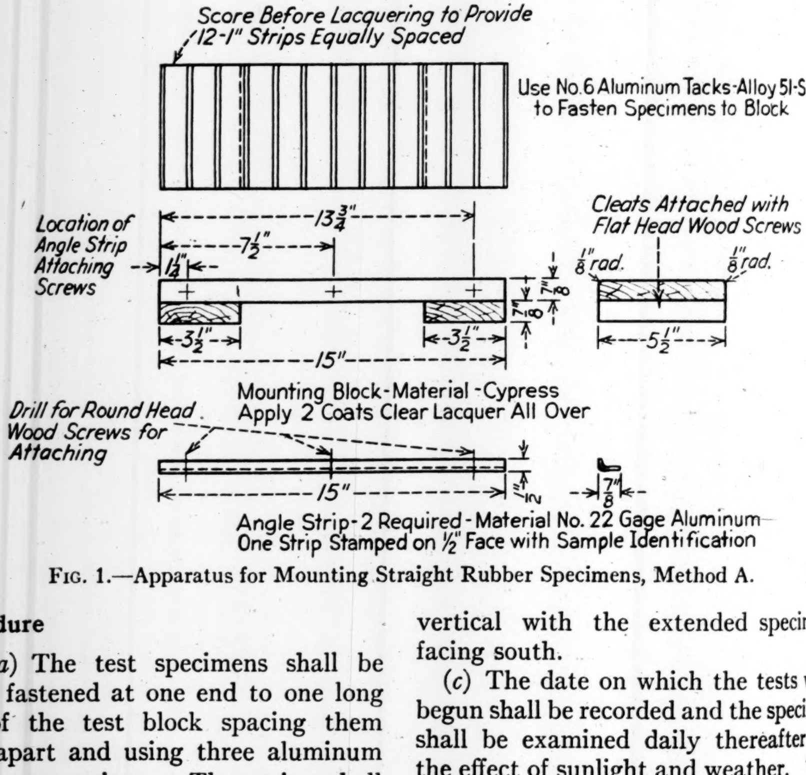
Score Before Lacquering to Provide 12-1" Strips Equally Spaced
Use No. 6 Aluminum Tacks-Alloy 51-S to Fasten Specimens to Block
Location of Angle Strip Attaching Screws
13¾"
7½"
1¼"
⅞
3½"
3½"
15"
Cleats Attached with Flat Head Wood Screws
⅛" rad.
⅛" rad.
5½"
Mounting Block-Material-Cypress
Apply 2 Coats Clear Lacquer All Over
Drill for Round Head Wood Screws for Attaching
15"
½
⅞"
Angle Strip-2 Required-Material No. 22 Gage Aluminum
One Strip Stamped on ½" Face with Sample Identification

FIG. 1.—Apparatus for Mounting Straight Rubber Specimens, Method A.

Procedure

5. (*a*) The test specimens shall be firmly fastened at one end to one long side of the test block spacing them $\frac{1}{4}$ in. apart and using three aluminum tacks per specimen. The strips shall then be drawn across the face of the block in such a manner as to cause an extension of 20 per cent measured between gage marks which shall be 4 in. apart centered at the middle of each strip. The other end of each specimen shall then be fastened in the same way to the opposite long side of the block. The aluminum shields shall then be mounted by means of screws on each of the long sides so that the $\frac{7}{8}$-in. leg covers the tacked ends of the specimens and the $\frac{1}{2}$-in. leg covers the specimen at the bend on to the face of the block.

(*b*) The extended specimens shall be exposed to the weather and sunlight, preferably on the roof of a building. The block holding the specimens shall be placed at an angle of 45 deg. from the vertical with the extended specimens facing south.

(*c*) The date on which the tests were begun shall be recorded and the specimen shall be examined daily thereafter for the effect of sunlight and weather. The time of the appearance of the first surface checking together with the time of the appearance of the first minute surface cracks on each specimen shall be recorded. If desired, the exposure may subsequently be continued for the purpose of observing the rate of growth of the cracks or the development of any characteristic or unusual surface effects.

Method B. Exposure of Looped Test Specimens

Apparatus

6. The apparatus shall consist of the following:

(*a*) *Clamping Strips.*—Strips made of a medium-soft wood for clamping the specimens. Each strip shall be $\frac{1}{2}$ in. in thickness, 1 in. in width, and 23 in. in length. Holes shall be drilled through the $\frac{1}{2}$-in. thickness of each strip at intervals of $1\frac{9}{16}$ in. starting $\frac{9}{16}$ in. from one end. The holes shall be made using a No. 22 drill (0.157 in. in diameter) and shall match in paired strips. The strips shall be fastened together using round-head chromium-plated or galvanized iron machine screws (commercial designation: diameter No. 6, thread No. 32, length $1\frac{1}{2}$ in.) fitted with nuts.

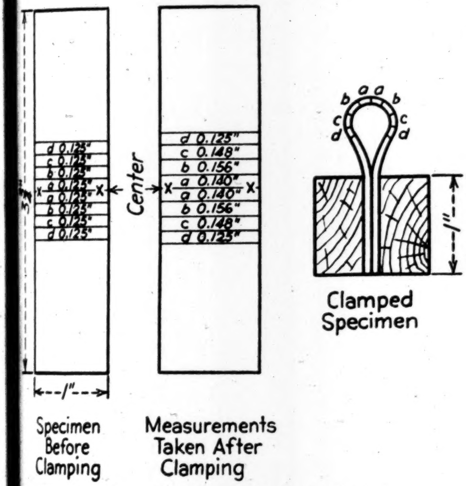

FIG. 2.—Cross-sectional View of Mounted Looped Specimen Showing Elongation at Different Parts, Method B.

(*b*) *Base Panel.*—A base panel made of medium-soft wood upon which the clamped specimens are mounted. It shall be 24 in. in length, 8 in. in width, and at least $\frac{1}{2}$ in. in thickness. Three cross-pieces each 8 in. in length, 1 in. in width, and $\frac{1}{4}$ in. in thickness shall be fastened to the base. The cross-pieces shall be mounted $\frac{3}{4}$ in. from each end of the panel and at the center. Each cross-piece shall be held in place by three 2-in. round-head chromium-plated or galvanized iron machine screws (commercial designation: diameter No. 6, thread No. 32, length 2 in.). These screws shall be fitted with $\frac{7}{16}$-in. washers on the underside of the base panel and shall fit into a $\frac{1}{2}$-in. counter-sink. The screws shall pass through the panel and through the cross-pieces, $1\frac{1}{4}$ in. from each end of the cross-pieces and through the center. These screws shall protrude above the surface of the panel to a height of about $1\frac{3}{8}$ in. and shall be used to fasten the wooden specimen strips securely to the base as described in Section 8 (*b*).

(*c*) All wooden panels, strips and cross-pieces shall be painted with two coats of Dulux Suede No. 93503 or duPont Clear Lacquer, or its equivalent.

Test Specimens

7. (*a*) The test specimens shall be rectangular strips 1 in. in width by $3\frac{3}{4}$ in. in length, cut longitudinally from standard laboratory test slabs having a thickness of 0.075 in. minimum and not to exceed 0.100 in.

(*b*) Duplicate test specimens shall be mounted whenever possible.

Procedure

8. (*a*) The test specimens shall be looped until their ends meet and these shall then be inserted between the paired wooden strips until they are flush with the underside of the strips. The minimum distance between specimens shall be $\frac{1}{4}$ in. The wooden strips shall then be clamped together by means of machine screws so that the specimens shall be firmly held in place. As a result of the above procedure, 1 in. of each end of the specimen will be

covered by the wooden strips which will act as a protective shield. The remaining 1¾ in. of the specimen shall form a loop having a varying elongation along its length as illustrated in Fig. 2.

(*b*) The rack of clamped specimens shall be mounted on the cross-pieces attached to the base panel by passing the protruding machine screws of the panel between the paired wooden strips and fastening with nuts and washers, as illustrated in Fig. 3.

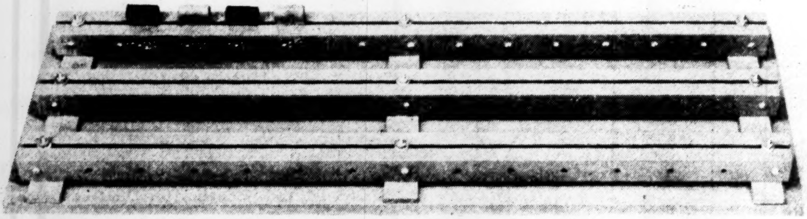

FIG. 3.—Assembled Panel, Showing Method of Mounting Looped Specimens.

(*c*) The looped specimens shall next be exposed to the weather and sunlight, preferably on the roof of a building. The panel holding the specimens shall be placed at an angle of 45 deg. from the vertical with the specimens facing south.

(*d*) The specimens shall be examined daily or as often as necessary for the effect of sunlight and weather. The time of appearance of checking as well as the time of appearance of initial surface cracking shall be recorded for each specimen. If desired the exposure may subsequently be continued for the purpose of observing the rate of growth of the cracks or the development of any characteristic or unusual surface effects.

Report

9. For each of the alternative methods, the report shall include the following:

(*a*) Statement of method used.

(*b*) Description of the specimens identifying the rubber compounds and giving the duration, temperature, and date of vulcanization if known.

(*c*) Dates of starting sunlight exposure and first appearance of surface checking and cracking.

(*d*) Geographical location of the place of exposure.

(*e*) Description of the appearance of the exposed specimens including, if feasible, a photographic record.

Tentative Specifications for
INSULATED WIRE AND CABLE: CLASS AO, 30 PER CENT HEVEA RUBBER COMPOUND[1]

A.S.T.M. Designation: D 27 - 38 T

Issued, 1916; Revised, 1921, 1928, 1931, 1933, 1934, 1935, 1936, 1937, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover the conductors, insulation, cable tape, cotton braid, and lead sheaths of Class AO rubber insulated wire and cable. The design and factor of safety depend upon the service conditions and shall be at the option of the purchaser.

Conductor

Material

2. The conductor shall be of soft annealed copper, properly tinned, and have the properties and characteristics specified in Sections 3 to 11.

Strand

3. Each individual wire of a stranded conductor shall be considered separately and shall be designated as a strand.

Shape

4. Each solid conductor and each strand shall be round and reasonably free from imperfections.

Stranding

5. The stranding shall conform to the Standard Specifications for Bare Stranded Copper Cable, Hard, Medium-Hard, or Soft (A.S.T.M. Designation: B 8, Table I, Class B or, where specified, Class C) of the American Society for Testing Materials.[2] If a more flexible stranding is specified in the order, it shall conform to the requirements shown in Table I.

Table I.—Stranding of Insulated Conductors.

Size of Conductor	Flexible Stranding, Number of Wires
No. 18 A.w.g.	16
No. 16 A.w.g.	26
No. 14 to No. 9 A.w.g.	37
No. 8 to No. 2 A.w.g.	49
No. 1 to No. 0000 A.w.g.	133
250 000 to 500 000 cir. mils	259
550 000 to 1 000 000 cir. mils	427
1 100 000 to 1 500 000 cir. mils	427
1 600 000 to 2 500 000 cir. mils	703

Density

6. For the purpose of calculating weights, cross-sections, etc., in con-

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] 1936 Book of A.S.T.M. Standards, Part I, p. 638.

ductivity determinations, the density of copper shall be taken as 8.89 g. per cu. cm. (See Appendix I.)

Permissible Variations in Diameter and Area

7. (*a*) *Permissible Variations.*—When the diameter of solid conductors and strands is specified, the permissible variation from the specified value shall not exceed 1 per cent under or 3 per cent over for wire 0.010 in. in diameter or larger, and 0.1 mil under or 0.3 mil over for wire less than 0.010 in. in diameter. When the area of cross-section of stranded conductors is specified, the permissible variation shall not exceed 1 per cent under the specified value.

(*b*) *Method of Gaging Diameter.*—When wire is submitted in coils, each coil shall be gaged in three places, one near each end and one approximately at the middle. When wire is submitted on spools or reels, approximately 12 ft. of the wire shall be reeled off and the wire then gaged in six places between the second foot and the twelfth foot from the end.

(*c*) *Calculation of Area.*—The area of cross-section of wire shall be calculated from the average of the measurements of the diameter made in accordance with Paragraph (*b*). The area of cross-section of cable shall be considered to be the sum of the cross-sectional areas of its component wires, when laid out straight and measured perpendicular to their axes.

(*d*) *Rejection.*—A coil or reel shall be rejected if the average diameter obtained from the measurements made in accordance with Paragraph (*b*), or the area calculated in accordance with Paragraph (*c*), is not within the limits specified in Paragraph (*a*). A coil or reel shall be rejected if any individual measurement of diameter or of area of cross-section is not within twice the limits of Paragraph (*a*).

Tensile Properties

8. (*a*) Each solid conductor and each strand previous to stranding shall be so drawn and annealed that after tinning it shall conform to the values shown in Table II.

(*b*) After stranding, the tensile strength of each strand shall not exceed that specified in Table II by more than 5 per cent, and the minimum elongation in 10 in. shall not be less than that specified in Table II by more than 5 per cent.

(*c*) For nominal diameters between listed sizes the requirements shall be those of the next larger sizes indicated in Table II.

TABLE II.—TENSILE REQUIREMENTS OF CONDUCTORS.

Size of Conductor		Tensile Strength, max., psi.	Elongation in 10 in., min., per cent
Diameter, in.	A.w.g. Number		
0.460 to 0.290....	0000 to 1....	36 000	30
0.289 to 0.103....	2 to 10....	37 000	25
0.102 to 0.021....	12 to 24....	38 500	20
0.020 to 0.012....	25 to 28....	39 000	15
0.011 to 0.003....	29 to 40....	40 000	10

Tension Tests

9. (*a*) Tension tests of the conductor shall be made on representative samples and the elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between gage marks originally 10 in. apart. The specimen shall break between the gage marks and not closer than 1 in. to either mark.

(*b*) *Retests and Rejections.*—If upon testing a sample from a coil, reel, or spool of wire, the results are found to be above the specified tensile strength or below the specified elongation, tests upon two additional samples will be made and the average of the three tests shall determine acceptance or rejection.

Conductivity

10. The conductivity of the conductors after tinning shall be not less than that specified in Table III.

NOTE.—The conductivity values in Table III conform to the International Annealed Copper Standard. (See Appendix I.)

TABLE III.—CONDUCTIVITY REQUIREMENTS.

DIAMETER, IN.	A.W.G. NUMBER	CONDUCTIVITY, PER CENT
0.460 to 0.290	0000 to 1.....	97.65
0.289 to 0.103	2 to 10.....	97.15
0.102 to 0.021	12 to 24.....	96.15
0.020 to 0.012	25 to 28.....	94.15
0.011 to 0.003	29 to 40.....	93.15

Tinning Test

11. (*a*) The continuity of the tin coating on each sample before stranding or insulating shall be determined by the sodium polysulfide test which shall be made as described in Sections 4 to 10, inclusive, of the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (A.S.T.M. Designation: B 33) of the American Society for Testing Materials.[3]

(*b*) *Retests and Rejections.*—If the specimens tested in accordance with Paragraph (*a*) show any signs of blackening, two more specimens shall be tested. If one of these two additional specimens shows any blackening, that coil or reel shall be rejected. If both specimens are free from any signs of blackening, the coil or reel shall be accepted. If more than 10 per cent of the samples in the entire order fail, all of the wire shall be rejected. If 10 per cent or less of the samples in the entire lot fail, each coil, reel, or length may be tested and accepted or rejected upon the results of the individual tests.

INSULATION

Rubber Compound

12. (*a*) Wires and cables ordered under these specifications shall be insulated with Class AO rubber compound.

(*b*) Where performance rubber compound is desired, the order shall be placed under the Tentative Specifications for Insulated Wire and Cable: Performance Rubber Compound (A.S.T.M. Designation: D 353)[4] and where heat-resisting compound is desired, under the Tentative Specifications for Insulated Wire and Cable: Heat-Resisting Rubber Compound (A.S.T.M. Designation: D 469)[4] of the American Society for Testing Materials.

Composition of Compound

13. (*a*) Class AO rubber compound shall contain exclusively not less than 30 per cent nor more than 33 per cent of the best quality Hevea rubber which has not previously been used in a rubber compound, solid waxy hydrocarbons, suitable mineral matter, antioxidants, organic accelerators, and sufficient sulfur to properly vulcanize the compound.

(*b*) The mineral matter shall be dry.

(*c*) The waxy hydrocarbons used shall be solid at 54 C. and shall be free from saponifiable matter.

(*d*) Contamination of the compound, such as by the use of impregnated tapes, will not excuse the manufacturer from conforming to these specifications.

Chemical Requirements

14. (*a*) *Quantitative Requirements.*—The insulation shall consist of a properly vulcanized rubber compound which after vulcanization shall conform on analysis to the following requirements expressed as percentages by weight of the whole sample:

Rubber, per cent............	30 to 33
Waxy hydrocarbons, max., per cent......................	4
Free sulfur, max., per cent.....	0.7

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[3] 1936 Book of A.S.T.M. Standards, Part I, p. 669.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 1109, 1096 (1937); also 1938 Book of A.S.T.M. Tentative Standards, pp. 1259, 1265.

	30 PER CENT RUBBER [a]	33 PER CENT RUBBER [a]
Saponifiable acetone extract, max., per cent	2.00	2.20
Unsaponifiable resins, max., per cent	1.00	1.10
Chloroform extract, max., per cent	0.90	1.00
Alcoholic potash extract, max., per cent	0.55	0.60
Total sulfur, max., per cent	2.10	2.30
Specific gravity, min	~~1.67[a]~~ 1.75[a]	~~1.75[a]~~ 1.67[a]

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[a] For percentages between 30 and 33, the specific gravity limits shall be in proportion to the percentage of rubber found.

(*b*) *Qualitative Requirements.*—The acetone solution shall not fluoresce. The hydrocarbons shall be solid, waxy, and not darker than a light brown. The chloroform extract (60 ml.) shall not be darker than a straw color.

Sampling for Analysis

15. Samples of the vulcanized rubber compound for chemical analysis shall be taken after the successful completion of the physical and electrical tests, and before applying impregnating compounds which may contaminate the rubber. The samples shall be taken at the option of the purchaser. The purchaser shall assure himself that all samples are free from contamination and change due to torch heating. Wherever practicable, samples shall be taken at a distance of at least 3 ft. from the end of the wire.

Physical Properties

16. The insulation shall conform to the requirements as to physical properties prescribed in Table IV.

TABLE IV.—PHYSICAL TEST REQUIREMENTS FOR INSULATION.

Tensile strength, min., psi	1200
Tensile stress at 200 per cent elongation, min., psi	300
Elongation at rupture, min., per cent	400
Set in 2-in. gage length, max., in	3/8
Depreciation in tensile strength and elongation after 96 hr. in air oven test at 157 to 159 F. (69.4 to 70.6 C.), max., per cent	15
Depreciation in tensile strength and elongation after 96 hr. in oxygen pressure test, max., per cent	25

High Voltage Test

17. Each coil, reel, or length of wire or cable, after vulcanization shall successfully withstand the application of an alternating-current voltage of not less than that prescribed in Table V for a period of 5 min.

Insulation Resistance

18. (*a*) Each coil, reel, or length of wire or cable after being subjected to the high voltage test specified in Section 17 shall have an insulation resistance not less than that prescribed in Table VI.

(*b*) In calculating insulation resistance, the temperature coefficients given in Table VII shall be used.

Moisture Absorption

19. (*a*) The increase in the specific inductive capacity of the insulation shall be used as an indication of the amount of moisture absorbed.

(*b*) The specific inductive capacity after 24-hr. immersion in water shall not exceed six. The increase between the ends of the first and the fourteenth days shall not exceed 20 per cent and that beween the ends of the seventh and fourteenth days shall not exceed 5 per cent.

(*c*) The specific inductive capacity shall be determined at either 1000 or 60 cycles. When measured at 1000 cycles, the voltage impressed upon the conductor shall not exceed 10 v. When measured at 60 cycles, the voltage impressed upon the conductor shall be equivalent to a stress of between 30 to 40 v. per mil of insulation.

Thickness

20. (*a*) The average thickness of the insulation shall be not less than that prescribed in Table V. The minimum thickness shall be not less than 95 per

TABLE V.—THICKNESS OF INSULATION AND ALTERNATING TEST VOLTAGE.

NOTE 1.—Rated circuit voltage of a-c. circuits is the phase-to-phase voltage.

NOTE 2.—For an intermediate size of wire or an intermediate rated circuit voltage, the thickness and the test voltage shall be that for the next larger size or higher rated circuit voltage.

NOTE 3.—For non-leaded submarine cables, $\frac{1}{32}$ in. should be added to the specified respective walls of insulation in this table for all sizes and voltages.

NOTE 4.—Rated circuit voltages from 0 to 5000 v. in this table apply to wire for use on grounded and ungrounded circuits.

NOTE 5.—Above 5000 v. a-c., special high-voltage rubber compounds are preferred according to manufacturer's recommendations.

Rated Circuit Voltage	Size of Conductor, A.w.g. Numbers or Circular Mils	Insulation Thickness on Each Conductor, sixty-fourths of an inch	Test Voltage
0 to 300	No. 18 to No. 16	2	1 000
0 to 600	No. 14 to No. 9	3	3 000
	No. 8 to No. 2	4	3 500
	No. 1 to No. 0000	5	4 000
	225 000 to 500 000 cir. mils	6	5 000
	525 000 to 1 000 000 cir. mils	7	6 000
	Over 1 000 000 cir. mils	8	7 000
601 to 1000	No. 14 to No. 8	4	5 000
	No. 7 to No. 2	5	6 000
	No. 1 to No. 0000	6	7 500
	225 000 to 500 000 cir. mils	7	9 000
	525 000 to 1 000 000 cir. mils	8	10 000
	Over 1 000 000 cir. mils	9	11 000
1001 to 2000	No. 14 to No. 8	5	6 000
	No. 7 to No. 2	6	7 500
	No. 1 to No. 0000	7	9 000
	225 000 to 500 000 cir. mils	8	10 000
	525 000 to 1 000 000 cir. mils	9	11 000
	Over 1 000 000 cir. mils	9	11 000
2001 to 3000	No. 14 to No. 8	7	9 000
	No. 7 to No. 2	8	10 000
	No. 1 to No. 0000	8	10 000
	225 000 to 500 000 cir. mils	9	11 000
	525 000 to 1 000 000 cir. mils	9	11 000
	Over 1 000 000 cir. mils	10	12 500
3001 to 4000	No. 14 to No. 8	9	11 000
	No. 7 to No. 2	9	11 000
	No. 1 to No. 0000	9	11 000
	225 000 to 500 000 cir. mils	10	12 500
	525 000 to 1 000 000 cir. mils	10	12 500
	Over 1 000 000 cir. mils	11	13 500
4001 to 5000	No. 14 to No. 8	10	12 500
	No. 7 to No. 2	10	12 500
	No. 1 to No. 0000	10	12 500
	225 000 to 500 000 cir. mils	11	13 500
	525 000 to 1 000 000 cir. mils	11	13 500
	Over 1 000 000 cir. mils	12	15 000
5001 to 6000 (grounded)	No. 14 to No. 0000	10	12 500
	225 000 to 1 000 000 cir. mils	11	13 500
	Over 1 000 000 cir. mils	12	15 000
5001 to 6000 (ungrounded)	No. 14 to No. 0000	12	15 000
	225 000 to 1 000 000 cir. mils	12	15 000
	Over 1 000 000 cir. mils	13	16 500
6001 to 7000 (grounded)	No. 8 to No. 0000	11	13 500
	225 000 to 1 000 000 cir. mils	11	13 500
	Over 1 000 000 cir. mils	12	15 000
6001 to 7000 (ungrounded)	No. 8 to No. 0000	14	17 500
	225 000 to 1 000 000 cir. mils	14	17 500
	Over 1 000 000 cir. mils	15	19 000
7001 to 8000 (grounded)	No. 8 to No. 0000	12	15 000
	225 000 to 1 000 000 cir. mils	12	15 000
	Over 1 000 000 cir. mils	13	16 500
7001 to 8000 (ungrounded)	No. 8 to No. 0000	16	20 000
	225 000 to 1 000 000 cir. mils	16	20 000
	Over 1 000 000 cir. mils	17	21 000

cent of the thickness required by Table V for insulations less than $\frac{4}{64}$ in. in thickness and not less than 90 per cent of the specified thickness for insulations of $\frac{4}{64}$ in. and greater.

TABLE VI.—INSULATION RESISTANCE.

Insulation Thickness In Sixty-fourths of an Inch			2	3	4	5	6	7	8	9	10	12
Size of Conductor, A.w.g. numbers or circular mils	Solid or Stranded	Diameter, in.	Insulation Resistance, megohms—1000 ft. at 60 F. (15.5 C.)									
No. 18	Solid	0.040	8600	11 100	.....	.....	.....	.....	.....	.....	.....	.....
No. 16	Solid	0.051	7300	9 500	.....	.....	.....	.....	.....	.....	.....	.....
No. 14	Solid	0.064	.....	8 300	9900	11 300	12 550	13 650	14 600	15 450	16 250	17 650
No. 12	Solid	0.081	.....	7 050	8550	9 850	11 000	12 000	12 900	13 750	14 500	15 850
No. 10	Solid	0.102	.....	6 000	7350	8 500	9 600	10 500	11 350	12 100	12 850	14 150
No. 8	Solid	0.128	.....	.....	6200	7 300	8 300	9 150	9 950	10 650	11 350	12 550
No. 6	Stranded	0.184	.....	.....	4750	5 600	6 400	7 200	7 900	8 500	9 100	10 200
No. 4	Stranded	0.232	.....	.....	3900	4 700	5 450	6 100	6 700	7 250	7 800	8 850
No. 2	Stranded	0.292	.....	.....	3250	3 900	4 550	5 150	5 650	6 150	6 650	7 600
No. 1	Stranded	0.332	.....	.....	.....	3 550	4 100	4 650	5 150	5 600	6 100	6 950
No. 0	Stranded	0.373	.....	.....	.....	3 200	3 750	4 200	4 700	5 150	5 550	6 350
No. 00	Stranded	0.418	.....	.....	.....	2 900	3 400	3 850	4 300	4 700	5 100	5 850
No. 000	Stranded	0.470	.....	.....	.....	2 600	3 100	3 500	3 900	4 250	4 650	5 400
No. 0000	Stranded	0.528	.....	.....	.....	2 400	2 800	3 150	3 550	3 900	4 200	4 900
250 000 cir. mils	Stranded	0.575	.....	.....	.....	.....	2 600	2 950	3 300	3 650	4 000	4 600
350 000 cir. mils	Stranded	0.681	.....	.....	.....	.....	2 250	2 550	2 850	3 150	3 450	4 000
500 000 cir. mils	Stranded	0.814	.....	.....	.....	.....	1 900	2 200	2 450	2 700	2 950	3 450
750 000 cir. mils	Stranded	0.998	.....	.....	.....	.....	.....	1 800	2 050	2 250	2 500	2 900
1 000 000 cir. mils	Stranded	1.152	.....	.....	.....	.....	.....	1 600	1 800	2 000	2 200	2 600
1 250 000 cir. mils	Stranded	1.289	.....	.....	.....	.....	.....	.....	1 600	1 800	2 000	2 350
1 500 000 cir. mils	Stranded	1.412	.....	.....	.....	.....	.....	.....	1 500	1 650	1 850	2 150
1 750 000 cir. mils	Stranded	1.526	.....	.....	.....	.....	.....	.....	1 400	1 550	1 700	2 000
2 000 000 cir. mils	Stranded	1.631	.....	.....	.....	.....	.....	.....	1 300	1 500	1 600	1 900

Insulation Thickness in Sixty-fourths of an Inch			13	14	15	16	17
Size of Conductor, A.w.g. numbers or circular mils	Solid or Stranded	Diameter, in.	Insulation Resistance, megohms—1000 ft. at 60 F. (15.5 C.)				
No. 8	Solid	0.128	13 100	13 600	14 100	14 600	14 900
No. 6	Stranded	0.184	10 650	11 150	11 500	12 000	12 450
No. 4	Stranded	0.232	9 300	9 700	10 100	10 500	10 900
No. 2	Stranded	0.292	7 950	8 400	8 800	9 150	9 500
No. 1	Stranded	0.332	7 350	7 650	8 000	8 400	8 750
No. 0	Stranded	0.373	6 750	7 050	7 400	7 800	8 100
No. 00	Stranded	0.418	6 200	6 500	6 900	7 150	7 500
No. 000	Stranded	0.470	5 700	6 150	6 350	6 650	6 900
No. 0000	Stranded	0.528	5 200	5 500	5 800	6 050	6 350
250 000 cir. mils	Stranded	0.575	4 900	5 200	5 450	5 750	5 950
350 000 cir. mils	Stranded	0.681	4 250	4 500	4 700	4 950	5 200
500 000 cir. mils	Stranded	0.814	3 700	3 950	4 150	4 350	4 550
750 000 cir. mils	Stranded	0.998	3 100	3 300	3 500	3 700	3 900
1 000 000 cir. mils	Stranded	1.152	2 750	2 950	3 100	3 300	3 450
1 250 000 cir. mils	Stranded	1.289	2 500	2 650	2 850	3 000	3 150
1 500 000 cir. mils	Stranded	1.412	2 300	2 450	2 600	2 700	2 950
1 750 000 cir. mils	Stranded	1.526	2 150	2 300	2 450	2 600	2 750
2 000 000 cir. mils	Stranded	1.631	2 050	2 200	2 300	2 450	2 600

NOTE 1.—This table is based on a constant, $K = 21,120$ in the following formula:

$$R = K \log_{10} \frac{D}{d}$$

where R = the insulation resistance in megohms—1000 ft.,
K = constant,
D = diameter over insulation, on each conductor, and
d = diameter over conductor.

NOTE 2.—For an intermediate size, the insulation resistance shall be that of the next larger size.

(*b*) The thicknesses prescribed in Table V apply to single conductor cable and the individual conductors of multiple-conductor cables, leaded or braided, except special applications such as aerial, non-leaded submarine, and vertical riser cable.

NOTE.—In Appendix II will be found an interpretation of the insulation thicknesses given in Table V.

(c) *Number of Measurements.*—When the lot of wire to be inspected consists of two coils or reels, or less, at least one determination of the thickness shall be made on each coil or reel. When the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of two coils or reels taken at random. If the lot consists of 20 or more coils or reels, not less than 10 per cent of the coils or reels shall be selected at random and at least one determination of the thickness made on each coil or reel so selected.

TABLE VII.—TEMPERATURE COEFFICIENTS.

Temperature		Temperature Coefficient	Temperature		Temperature Coefficient
Fahrenheit Deg.	Centigrade Deg.		Fahrenheit Deg.	Centigrade Deg.	
46	7.8...	0.69	61	16.1...	1.03
47	8.3...	0.71	62	16.7...	1.05
48	8.9...	0.73	63	17.2...	1.08
49	9.4...	0.75	64	17.8...	1.11
50	10.0...	0.77	65	18.3...	1.14
51	10.6...	0.79	66	18.9...	1.17
52	11.1...	0.81	67	19.4...	1.20
53	11.7...	0.83	68	20.0...	1.23
54	12.2...	0.85	69	20.6...	1.26
55	12.8...	0.88	70	21.1...	1.30
56	13.3...	0.90	71	21.7...	1.33
57	13.9...	0.92	72	22.2...	1.37
58	14.4...	0.94	73	22.8...	1.40
59	15.0...	0.97	74	23.3...	1.44
60	15.6...	1.00	75	23.9...	1.48

(d) *Measurement of Thickness.*—The thickness measurements may be made with any type of micrometer reading to 0.001 in., suitable for measurements of this character. The average thickness of the insulation shall be taken as one-half the difference between the mean of the maximum and minimum diameters measured at any one point and the average diameter of the conductor measured at the same point. The minimum thickness shall be taken as the difference between a measurement made over the conductor plus the thinnest wall and the diameter of the conductor. (The first measurement is made by "slicing off" the heavier side of the insulation.) In the case of multiple-conductor cable, the measurements shall be made on the individual wires before being cabled.

Workmanship

21. (*a*) The insulation shall be homogeneous in character, tough, elastic, and applied concentrically about the conductor and shall fit tightly thereto. Where the insulation is applied in more than one layer, adjacent layers shall be vulcanized into a homogeneous mass.

(*b*) *Shielding.*—Braided cables not supported on insulators when operating at 6001 v. and over with the neutral grounded, or 3501 v. and over with the neutral ungrounded shall be shielded or suitably protected against corona. For special installations, such as braided cables connected to an overhead line, shielding may be provided at voltages lower than those given herein. All lead-covered multiple-conductor cables operating at 6001 v. and over with the neutral ungrounded shall be shielded or suitably protected against corona. The shielding shall consist of a tinned copper tape at least 3 mils thick or braid of fine tinned copper wires.

(*c*) *Covering.*—The insulation of braided wires up to No. 7 A.w.g., inclusive, shall be covered with a single cotton braid. In multiple-conductor cables the individual conductors shall not be braid-covered unless so specified. On larger sizes the fibrous covering shall consist of a cable tape and a cotton braid or two cotton braids. The cable tape shall conform to the requirements specified in Sections 24 to 26, inclusive. The cotton braid shall be applied in accordance with Sections 27 to 32, inclusive, and shall be finished in accordance with Sections 33 to 37.

(*d*) *Repairs or Joints.*—Where repairs or joints are made in the insulation, the work shall be done in such manner that the repaired part of the joint, and all parts affected in the process, shall be as strong and durable electrically and mechanically as the remainder of the insulation and shall not exceed the limitations on the thickness specified in Section 20.

Rejection

22. (*a*) If the thickness of the insulation of any coil or reel is found to be less than the specified value, that coil or reel shall be rejected and a thickness measurement on each of the remaining coils or reels shall be made.

(*b*) The purchaser may make a chemical analysis on any one of the samples selected as described in Section 15 to determine if the compound conforms to the requirements of Section 14. Failure of any sample selected to conform to the requirements shall be sufficient cause for rejecting the wire which that sample represents, except in the case of failure to conform to the requirements for either or both free sulfur and chloroform extract. In case of such failure, the coil from which the sample was taken shall be rejected and two additional samples shall be selected from the remainder of the order. The remainder of the order shall be accepted if both samples so selected conform to the requirements for free sulfur or chloroform extract. The entire order shall be rejected if either sample fails.

(*c*) When ten or more samples are selected in any inspection lot, all coils, reels, or lengths may be rejected if more than 10 per cent of the samples fail to conform to the requirements as to physical properties. If 10 per cent or less fail, each coil, reel, or length may be tested and shall be accepted or rejected upon the results of such individual tests. When the number of samples selected in any inspection lot is less than ten, all coils, reels, or lengths shall be rejected if more than 20 per cent of the samples fail. If 20 per cent or less fail, each coil, reel, or length may be tested and shall be accepted or rejected upon the result of such individual tests.

(*d*) Each coil, reel, or length which fails to comply with the electrical requirements of these specifications shall be rejected.

Methods of Test

23. (*a*) *Chemical Analysis.*—The analytical tests necessary for determining conformity to the chemical composition requirements in Section 14 shall be made in accordance with the complete procedure as described in the Standard Methods of Chemical Analysis of Rubber Products (A.S.T.M. Designation: D 297) of the American Society for Testing Materials.[5]

(*b*) *Physical and Electrical Tests.*—All measurements and tests necessary for determining conformity of the insulation to these specifications shall be made in accordance with the Tentative Methods of Testing Rubber Insulated Wire and Cable (A.S.T.M. Designation: D 470) of the American Society for Testing Materials,[6] except as otherwise prescribed in these specifications.

CABLE TAPE

Material

24. Cable tape shall be made from cotton cloth having a weight of not less than 1 lb. per 4 yd. based on a width of 36 in. and not less than 56 by 60 picks

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[5] 1938 Supplement to Book of A.S.T.M. Standards, p. 202.

[6] See p. 1127.

per inch, and shall be frictioned on both sides and thoroughly filled with a rubber compound. The nominal thickness shall be 0.012 in. and not less than 0.011 in.

Application

25. The tape shall be applied helically and may be applied before vulcanization. The maximum width and minimum overlap shall conform to the values in Table VIII.

TABLE VIII.—WIDTH AND OVERLAP OF RUBBER-FILLED CABLE TAPE.

DIAMETER OVER INSULATION, IN.	MAXIMUM WIDTH OF TAPE, IN.	MINIMUM OVERLAP, IN.	MINIMUM OVERLAP, PER CENT
0 to 0.250	$1\frac{1}{2}$	$\frac{3}{16}$	12.5
0.251 to 0.500	2	$\frac{1}{4}$	12.5
0.501 to 0.750	$2\frac{1}{2}$	$\frac{5}{16}$	12.5
0.751 to 1.00	3	$\frac{3}{8}$	12.5
1.001 to 1.500	4	$\frac{1}{2}$	12.5
1.501 to 2.000	5	$\frac{5}{8}$	12.5

Number of Tests

26. Samples shall be taken at the option of the purchaser.

COTTON BRAID

Braids

27. Two types of cotton braid are covered in these specifications, as follows:

Standard Braid, designed for indoor service and installation in conduits.

Heavy Braid, designed for outdoor and rough service.

28. Unless otherwise specified, standard braid shall be supplied under these specifications.

Material

29. Cotton braid shall be closely woven from cotton thread having not less than two plies.

Construction

30. (*a*) The braid shall be so constructed that the tangent of the angle between the cotton thread and the side of the wire shall be not less than that specified in Table IX.

TABLE IX.—TANGENT OF ANGLE OF BRAID.

DIAMETER UNDER BRAID, IN.	VALUE OF TANGENT	CORRESPONDING BRAID ANGLE, DEG.
0 to 1.00	0.700	35
1.001 to 1.500	0.839	40
1.501 and over	1.000	45

(*b*) The thickness of standard braid shall be not less than that specified in Table X and that of heavy braid not less than that specified in Table XI.

TABLE X.—MINIMUM THICKNESS OF STANDARD BRAID

DIAMETER UNDER BRAID, IN.	MINIMUM THICKNESS OF STANDARD BRAID, IN.	CORRESPONDING MINIMUM SIZE AND PLY OF COTTON YARN
0 to 0.200	0.016	30/2
0.201 to 0.350	0.017	26/2
0.351 to 0.800	0.020	20/2
0.801 to 1.500	0.026	12/2
1.501 to 3.000	0.032	8/2

TABLE XI.—MINIMUM THICKNESS OF HEAVY BRAID.

DIAMETER UNDER BRAID, IN.	MINIMUM THICKNESS OF HEAVY BRAID, IN.	CORRESPONDING MINIMUM SIZE AND PLY OF COTTON YARN
0 to 0.200	0.020	20/2
0.201 to 0.300	0.022	16/2
0.301 to 0.600	0.026	12/2
0.601 to 1.000	0.032	8/2
1.001 to 1.500	0.037	6/2
1.501 to 2.000	0.045	4/2
2.001 to 3.000	0.056	4/3

(*c*) The number of carriers and the number of ends per carrier used in applying the braid shall be optional providing all other limitations of Sections 29 and 30 are met. The picks per inch shall be not less than the value as calculated by the following formula:

$$P = \sqrt{\left[\frac{1}{tE + M}\right]^2 - \left[\frac{C}{2\pi(D + T)}\right]^2}$$

where:

P = the picks per inch,

T = the thickness of braid, in inches, $T = 2t$

t = the thickness of one end of cotton, in inches $= \dfrac{0.0279\,K}{\sqrt{S}}$

K = cabling factor for plied yarn,

$$\text{values of } K \text{ are: } \left\{\begin{array}{l} 2 \text{ ply} = 1.60 \\ 3 \text{ ply} = 2.00 \\ 4 \text{ ply} = 2.36 \end{array}\right.$$

S = the cotton ply, size or number,

E = the number of ends per carrier,

C = the number of carriers,

D = the diameter under braid, in inches,

M = the space between each set of carrier threads, in inches,

$$M = X\ (0.011 + 7.0\ t^2E^2)$$

X = the closeness constant:

VALUES OF X	DIAMETER UNDER BRAID, IN.
1.1	0 to 0.500
1.0	0.501 and over

For convenience in calculating the more usual braid constructions, the formula for picks may be reduced to:

$$P = \sqrt{Y - \frac{Z}{(D + T)^2}}$$

where:

$$Y = \frac{1}{(tE + M)^2}$$

and

$$Z = \left(\frac{C}{2\pi}\right)^2$$

Values of Y for some of the most commonly used cottons are given in Table XII.

Values of Z for the standard braiders are:

NUMBER OF CARRIERS	VALUES OF Z
12	3.65
16	6.49
20	10.13
24	14.59
36	32.80
48	58.40

(*d*) For braid over twin wires use 1.64 times the conductor diameter to determine the proper braid.

(*e*) When two braids are specified, the outer braid shall be determined by the diameter over the inner braid. When the diameter change-over limit is such that Table X or Table XI and this section require different sizes of yarn on the inner and outer braids, both braids may be of the size of yarn as required on the outer braid.

(*f*) When two braids are applied in one operation, these specifications shall apply to the inner and outer braids except that picks per inch and angle of braid for inner braid shall be governed by the construction of the machine.

TABLE XII.—VALUES OF Y.

Size and Ply of Cotton Yarn	Thickness of Braid, T	Values of Y										
		For Diameters Under 0.500 in.				For Diameters 0.501 in. and Over						
		2 End	3 End	4 End	5 End	2 End	3 End	4 End	5 End	6 End	7 End	8 End
30/2	0.0163....	1081	592	358	233	...	...	...	...	...	...	...
26/2	0.0175....	982	526	312	220	...	...	...	...	...	...	...
24/2	0.0182....	930	492	290	185	...	...	...	...	...	...	...
20/2	0.0200....	807	416	241	151	878	446	259	163	...	...	...
16/2	0.0223....	683	339	193	118	738	365	207	127	...	...	...
14/2	0.0238....	616	302	168	103	664	324	180	111	...	...	...
12/2	0.0258....	538	257	142	85	582	276	152	92	59	40	28
10/2	0.0282....	...	...	...	...	497	231	125	74	48	32	22
8/2	0.0316....	...	...	...	...	407	183	96	56	35	23	16

(*g*) These specifications do not apply to braids for fixture wire or to fancy or special braids.

(*h*) In Table XIII are tabulated the required picks per inch as calculated by the formula in Paragraph (*c*) and the corresponding braid angle for braids applied with the minimum size and ply of cotton, and a definite number of ends per carrier. However, it is not the intent of these specifications to limit the braids to the scope of Table XIII since heavier cottons or a variation in ends per carrier are permissible providing all requirements of Sections 29 and 30 are fulfilled.

Measurements

31. The various quantities shall be determined as follows:

(*a*) *Diameter Under Braid*, by a suitable micrometer reading.

(*b*) *Number of Carriers* and *Ends per Carrier*, by examination of braid.

TABLE XIII.—TYPICAL BRAID CONSTRUCTIONS.

Diameter Under Braid, *D*, in.	Size and Ply of Cotton Yarn, min.	Number of Ends	Thickness of Braid, min., in.	Diameter Mean Avg. $(D+T)$, in.	12-Carrier Braiders		16-Carrier Braiders		20-Carrier Braiders		24-Carrier Braiders		36-Carrier Braiders		48-Carrier Braiders	
					Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.
STANDARD BRAID																
0.090	30/2	2	0.0163	0.106	27.7	57.0	22.6	43.0	.....	.....	.....	.....	.....	.....	.....	.....
0.091 to 0.110	30/2	2	0.0163	0.116	28.6	60.0	24.7	48.0	.....	.....	.....	.....	.....	.....	.....	.....
0.111 to 0.125	30/2	2	0.0163	0.134	29.8	65.0	27.0	55.0	23.0	44.0	.....	.....	.....	.....	.....	.....
0.126 to 0.150	30/2	2	0.0163	0.154	30.6	68.0	28.6	60.0	25.8	51.0	.....	.....	.....	.....	.....	.....
0.151 to 0.175	30/2	2	0.0163	0.179	31.2	71.0	29.8	64.0	27.8	58.0	.....	.....	.....	.....	.....	.....
0.176 to 0.200	30/2	2	0.0163	0.204	31.6	73.0	30.6	68.0	29.1	62.0	.....	.....	.....	.....	.....	.....
0.201 to 0.225	26/2	2	0.0175	0.231	30.2	74.3	29.3	69.4	28.1	63.9	26.6	58.1	.....	.....	.....	.....
0.226 to 0.250	26/2	2	0.0175	0.256	30.4	76.2	29.7	71.5	28.8	66.7	27.6	61.6	.....	.....	.....	.....
0.251 to 0.300	26/2	2	0.0175	0.293	30.4	78.0	30.2	74.0	29.5	70.0	28.6	65.0	.....	.....	.....	.....
0.301 to 0.350	26/2	2	0.0175	0.343	.....	.....	.....	.....	30.0	73.0	29.4	69.0	.....	.....	.....	.....
0.351 to 0.400	20/2	3	0.020	0.396	.....	.....	.....	.....	18.8	66.0	18.0	62.0	.....	.....	.....	.....
0.401 to 0.450	20/2	3	0.020	0.445	.....	.....	.....	.....	19.1	70.0	18.5	65.0	.....	.....	.....	.....
0.451 to 0.500	20/2	3	C.020	0.495	.....	.....	.....	.....	19.4	72.0	18.9	68.0	.....	.....	.....	.....
0.501 to 0.600	20/2	3	0.020	0.570	.....	.....	.....	.....	20.4	75.0	20.1	72.0	.....	.....	.....	.....
0.601 to 0.800	20/2	3	0.020	0.720	.....	.....	.....	.....	20.6	78.0	20.5	76.0	.....	.....	.....	.....
0.801 to 1.000	12/2	4	0.0258	0.925	.....	.....	.....	.....	11.8	73.7	11.6	70.3	10.7	59.8	9.2	48.6
1.001 to 1.200	12/2	4	0.0258	1.125	.....	.....	.....	.....	12.0	76.8	11.9	74.0	11.2	65.7	10.3	56.0
1.201 to 1.500	12/2	4	0.0258	1.376	.....	.....	.....	.....	.....	.....	12.0	77.0	11.6	70.2	11.0	63.2
1.501 to 2.000	8/2	5	0.0316	1.782	.....	.....	.....	.....	.....	.....	7.2	73.3	6.8	64.6	6.1	55.0
2.001 to 3.000	8/2	5	0.0316	2.532	.....	.....	.....	.....	.....	.....	7.3	78.2	7.1	72.2	6.9	66.2
HEAVY BRAID																
0.090	20/2	2	0.020	0.110	22.6	52.5	16.5	35.5	.....	.....	.....	.....	.....	.....	.....	.....
0.091 to 0.110	20/2	2	0.020	0.120	23.6	56.0	18.9	41.7	.....	.....	.....	.....	.....	.....	.....	.....
0.111 to 0.125	20/2	2	0.020	0.138	24.6	58.3	21.5	49.3	.....	.....	.....	.....	.....	.....	.....	.....
0.126 to 0.150	20/2	2	0.020	0.158	25.7	64.6	23.3	55.3	20.0	44.8	.....	.....	.....	.....	.....	.....
0.151 to 0.175	20/2	2	0.020	0.183	26.4	67.5	24.8	60.5	22.7	52.5	19.2	42.5	.....	.....	.....	.....
0.176 to 0.200	20/2	2	0.020	0.208	26.9	70.4	25.5	65.8	23.7	57.0	21.6	49.5	.....	.....	.....	.....
0.201 to 0.225	16/2	2	0.0223	0.235	.....	.....	23.8	56.5	22.4	58.8	20.4	51.5	.....	.....	.....	.....
0.226 to 0.250	16/2	2	0.0223	0.260	.....	.....	25.8	77.8	23.0	62.0	21.6	55.6	.....	.....	.....	.....
0.251 to 0.300	16/2	3	0.0223	0.297	.....	.....	16.3	62.3	15.0	54.5	13.2	49.5	.....	.....	.....	.....
0.301 to 0.350	12/2	3	0.0258	0.351	.....	.....	.....	.....	13.2	55.4	11.8	47.3	.....	.....	.....	.....
0.351 to 0.400	12/2	3	0.0258	0.401	.....	.....	.....	.....	13.9	60.1	12.9	53.5	.....	.....	.....	.....
0.401 to 0.450	12/2	3	0.0258	0.451	.....	.....	.....	.....	14.4	63.9	13.6	58.1	.....	.....	.....	.....
0.451 to 0.500	12/2	3	0.0258	0.501	.....	.....	.....	.....	14.7	66.6	14.1	62.0	.....	.....	.....	.....
0.501 to 0.600	12/2	3	0.0258	0.576	.....	.....	.....	.....	.....	.....	15.2	66.4	13.3	55.7	.....	.....
0.601 to 0.800	8/2	3	0.0316	0.732	.....	.....	.....	.....	.....	.....	12.5	67.3	11.1	57.2	.....	.....
0.801 to 1.000	8/2	3	0.0316	0.932	.....	.....	.....	.....	.....	.....	12.9	72.3	12.0	65.0	10.8	53.0
1.001 to 1.200	6/2	2	0.037	1.137	.....	.....	.....	.....	.....	.....	.....	.....	17.0	74.9	16.4	67.7
1.201 to 1.500	6/2	2	0.037	1.387	.....	.....	.....	.....	.....	.....	.....	.....	17.2	77.7	16.8	71.8
1.501 to 2.000	4/2	3	0.0446	1.795	.....	.....	.....	.....	.....	.....	.....	.....	8.6	71.3	8.1	62.3
2.001 to 3.000	4/3	3	0.0556	2.556	.....	.....	.....	.....	.....	.....	.....	.....	6.6	72.8	6.3	64.5

(*c*) *Picks per Inch*, on a 4-in. sample after wiping off outside of braid with chloroform.

(*d*) *Angle of Braid* by formula:

$$\text{Tangent of Angle} = \frac{2\pi P(D+T)}{C}$$

(*e*) *Thickness of Braid.*—A sample of braid approximately 2 in. in length shall be carefully slit and removed from the completed wire and immersed in chloroform or other suitable solvent for 5 min. The solvent shall be decanted and the operation repeated until the cotton is substantially free of saturating and finishing material. The sample shall then be dried by pressing between blotting papers. The extracted sample shall be measured by means of a dial micrometer having a presser foot 0.4 in. in diameter and a weight on the sample of 50 g. Five readings shall be made at different points on the sample and the average taken as the thickness of the braid. In the case of a double braid, each braid shall be removed and measured separately.

Number of Tests

32. Samples shall be taken at the option of the purchaser.

FINISH

Finish

33. The braid shall be completely saturated and finished with a black moisture-resistant compound. The surface of the wire shall be smooth and free from tackiness. The finish shall be capable of meeting the tests described in Sections 34 to 37, inclusive. Single conductor 600-v. wire for building purposes is required by the National Electrical Code to have a flame-proof finish. Where Underwriters' Laboratories', Inc. jurisdiction applies the finish and tests shall be in accordance with Underwriters' Laboratories', Inc. standards.

Bend Test

34. (*a*) *Sample.*—Each sample for the bend test shall be wrapped as specified in Paragraph (*b*) around a mandrel of the diameter prescribed in the following table:

DIAMETER OF SAMPLE, IN.	RATIO OF MANDREL DIAMETER TO OUTSIDE DIAMETER OF WIRE OR CABLE
0 to 0.250	1½
0.251 to 0.375	2¼
0.376 to 0.500	3
0.501 to 0.750	4½
0.751 to 1.000	6
1.001 to 1.500	9
1.501 and up	12

(*b*) *Test Procedure.*—The samples shall be held at a temperature of 32 F. (0 C.) for approximately 1 hr. before bending, and upon removal from the cooling chamber shall be wrapped upon the mandrel at an approximately uniform rate not greater than 12 turns per minute. Single conductor No. 2 A.w.g. and smaller shall be wrapped three times around the mandrel; when requested single-conductor wires larger than No. 2 A.w.g. and any multiple conductor shall be wrapped once around the mandrel.

(*c*) *Flaking and Cracking.*—The finishing material shall not flake off the wire or cable during the bend test or as a result of the bend test without actually rubbing the surface of the wire. Cracking of the finish will not be cause for rejection.

Melt Test

35. A piece of clean, white, glazed paper shall be wrapped around a 6-in. sample of finished wire or cable and this shall be suspended horizontally in an electrically heated oven, equipped with suitable automatic temperature control, which has been heated to 125 F. (52 C.) and the wire or cable shall be maintained at this temperature for 30 min. The wire or cable with the paper wrapping shall be cooled before inspection. The wire shall be rejected if the compound becomes sufficiently fluid to be transferred to the paper or form a ridge perceptible to the finger upon it.

Drip Test

36. Samples for the drip test shall be cut in lengths of 6 in. and the wire bared for a distance of ¾ in. from each end. The sample with one end secured in a suitable clamp shall then be suspended at an angle of 45 deg. in an electrically heated oven, equipped with suitable automatic temperature control, which has been heated to 180 F. (82.2 C.) and the wire or cable shall be maintained at this temperature for 1 hr. At the end of this time the compound shall not have dripped, flowed onto the surface of the

lower bared end of the conductor, formed globules on the lower side of the sample or bubbles upon its surface.

Saturating and Finishing Compounds

37. The saturating and finishing compounds shall have no injurious effect upon the rubber insulation or the coverings during application.

LEAD SHEATHS

Composition

38. (*a*) Lead sheaths shall consist of Grade II Chemical Lead or Grade III Common Lead not less than 99.85 per cent pure as specified in the Standard Specifications for Pig Lead (A.S.T.M. Designation: B 29) of the American Society for Testing Materials.[7] It shall be obtained from properly branded pig lead.

TABLE XIV.—THICKNESS OF LEAD SHEATHS.

DIAMETER OF CORE, IN.[a]	THICKNESS OF SHEATH, SIXTY-FOURTHS OF AN INCH
Over 3.000	9
2.001 to 3.000	8
1.501 to 2.000	7
1.051 to 1.500	6
0.701 to 1.050	5
0.426 to 0.700	4
0.000 to 0.425	3

[a] For twin cables, use the major axis.

(*b*) Lead sheaths shall be tightly formed around the core of the wire or cable.

Thickness

39. Lead sheaths shall have an average thickness not less than that indicated in Table XIV and the minimum thickness shall in no place be less than 90 per cent of the required average thickness.

Measurement

40. A short section of the lead sheath shall be removed from the wire or cable and the thickness measured with a suitable micrometer caliper at not less than ten points, of approximately equal spacing, care being taken to include the thinnest and the thickest parts.

INSPECTION AND REJECTION

Inspection and Test

41. (*a*) Inspection shall be made prior to shipment and at the place of manufacture.

(*b*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the wire or cable to permit of arrangements for inspection.

(*c*) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wire ordered, except compounding room. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications.

(*d*) The purchaser at his option may make the various tests on samples in his own laboratory or elsewhere, but such tests shall be made at the expense of the purchaser.

Rejection

42. Each coil, reel, or length which fails to conform to the physical and electrical requirements of these specifications shall be rejected.

Rehearing

43. Samples of rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time. Sealed duplicate samples may be retained by the manufacturer at his option.

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[7] 1936 Book of A.S.T.M. Standards, Part I, p. 678.

APPENDIX I

ANNEALED COPPER STANDARD[8]

The following shall be taken as normal values for standard annealed copper:

(*a*) *Resistance.*—At a temperature of 20 C. the resistance of a wire of standard annealed copper 1 m. in length and of a uniform section of 1 sq. mm. is $\frac{1}{58}$ ohm = 0.017241 ohm.

(*b*) *Density.*—At a temperature of 20 C. the density of standard annealed copper is 8.89 g. per cu. cm.

(*c*) *Temperature Coefficient of Resistance.*—At a temperature of 20 C. the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 per deg. Cent.

(*d*) Other values of resistivity of standard annealed copper at 20 C. deduced from Paragraphs (*a*) and (*b*) are as follows:

Resistance of a wire of uniform section, 1 meter long and weighing 1 g. = 0.15328 ohm.

Resistance of a wire with a uniform section of 1 cir. mil and 1 ft. long = 10.371 ohm.

Resistance between opposite faces of 1 cu. cm. = 1.7241 microhm.

Resistance between opposite faces of 1 cu. in. = 0.67879 microhm.

APPENDIX II

INTERPRETATION OF INSULATION THICKNESSES OF TABLE V

For series-street-lighting cable, use the following procedure:

A1. (*a*) If the transformer is not equipped with protectors, use the open circuit secondary voltage of the transformer as rated voltage of the cable and select the proper wall thickness from Table V.

(*b*) If the transformer is equipped with protectors, use the closed or loaded secondary voltage of the transformer as the rated circuit voltage of the cable and select the proper wall thickness from Table V.

> NOTE.—It is preferable, both in Paragraphs (*a*) and (*b*) above, to select a cable with a higher voltage rating than obtained using the above procedure, both as a measure of safety and to allow the substitution of a larger transformer without necessitating the replacement of the cable.

The thickness of insulation for the various systems shall be determined as follows:

A2. (*a*) For three-phase systems with grounded or ungrounded neutral, use thickness values in accordance with Table V.

(*b*) For single or two-phase systems up to and including 5000 v., use thickness values in accordance with Table V, as specified for grounded neutral. Where it is not definitely specified that a line operates as an isolated single or two-phase system it shall be considered as a branch of a grounded three-phase circuit and the thickness of insulation shall be that required by the phase-to-phase voltage of this grounded, three-phase circuit as given in Table V.

(*c*) For single or two-phase systems operating at over 5000 v. with one side grounded, multiply the circuit voltage (phase-to-phase) by 1.73 and use the resulting voltage value to select the corresponding insulation thickness for grounded neutral as specified in Table V.

(*d*) For single or two-phase systems operating at over 5000 v. with the center grounded, multiply the circuit voltage (phase-to-phase) by 0.866 $(\frac{1}{2}\sqrt{3})$ and use the resulting voltage value to select the corresponding insulation thickness for grounded neutral as specified in Table V.

(*e*) For single or two-phase ungrounded systems operating at over 5000 v., multiply the circuit voltage (phase-to-phase) by 0.866 $(\frac{1}{2}\sqrt{3})$ and use the resulting voltage value to select the corresponding insulation thickness for ungrounded neutral as specified in Table V.

(*f*) For direct-current systems, consider the same as single-phase alternating-current systems in accordance with Paragraph A2 (*b*).

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[8] Extracts from American Institute of Electrical Engineers' Standard No. 30 (1932).

TENTATIVE SPECIFICATIONS
FOR
SINGLE-PLY BLEACHED COTTON BROADCLOTH[1]

A.S.T.M. Designation: D 504 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications apply to single-ply bleached cotton broadcloth or general use.

Nature of Material Covered

2. Single-ply bleached cotton broadcloth shall be a plain-woven cotton fabric, usually mercerized, made of single yarns either carded or combed, having approximately twice as many warp as filling yarns per inch, but not less than 100 warp yarns and 54 filling yarns per inch, a breaking strength of not less than 52 lb. warpwise and 18 lb. fillingwise by the raveled strip method or not less than 56 lb. warpwise and 20 lb. fillingwise by the grab method, a width between 35 and 37 in., weighing not less than 3 oz. per sq. yd., and containing not over 4 per cent sizing.

TABLE I.—PHYSICAL PROPERTIES OF SINGLE-PLY BLEACHED COTTON BROADCLOTH (FINISHED).

			Type 1	Type 2
Yarn, character			carded	carded or combed
Count, min., yarns per in.	Warp		100	132
	Filling		54	58
Weight, min., oz. per sq. yd			3.0	3.1
Breaking strength, min., lb.	Grab test	Warp	56	76
		Fiilng	20	24
	Raveled strip test	Warp	52	66
		Filling	18	22
Sizing, max., per cent			4.0	2.0

Classification

3. Single-ply bleached cotton broadcloth shall be classified in the following types:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

	TOTAL NUMBER OF YARNS PER INCH (WARP PLUS FILLING)
Type 1 (low count)	less than 180
Type 2 (high count)	180 and above

Physical Properties

4. Single-ply bleached cotton broadcloth shall conform to the requirements specified in Table I.

Methods of Testing

5. (*a*) All test procedures, except as specified in Paragraph (*b*), shall be in accordance with the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

(*b*) *Sizing.*—The amount of sizing shall be determined in accordance with Section 3 of the Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (A.S.T.M. Designation: D 276 – 37 T) of the American Society for Testing Materials.[2]

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 220.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1174 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1407.

TENTATIVE SPECIFICATIONS
FOR
BLEACHED WIDE COTTON SHEETING[1]

A.S.T.M. Designation: D 503 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

1. These specifications apply to bleached wide cotton fabrics to be used for bed sheeting.

Nature of Material Covered

2. Bleached wide cotton sheeting shall be a plain-woven fabric made entirely of single yarns, either carded or combed, having not less than 56 yarns per inch both warpwise and fillingwise, a breaking strength (grab method) of not less than 50 lb. warpwise and 45 lb. fillingwise, weighing not less than 3.6 oz. per sq. yd., and containing not over 8.5 per cent sizing.

Table I.—Physical Properties of Bleached Wide Cotton Sheeting (Finished)

		Percale	Muscale	Unnamed	Muslin		
					Grade A	Grade B	Grade C
Character of yarn		combed	combed or carded	carded	carded	carded	carded
Count, min., yarns per in.	Warp	104	94	84	74	68	56
	Filling	98	84	80	66	60	56
Weight, oz. per sq. yd.	max	4.0	4.0	4.0	...	...	...
	min	3.6	3.7	...	4.6	4.2	3.9
Breaking strength, min., lb. (grab test)	Warp	60	60	50	70	60	50
	Filling	60	60	50	70	50	45
Sizing, max., per cent		1.0	1.0	1.0	2.0	5.0	8.5

Classification

3. Bleached wide cotton sheeting shall be classified in the following groups on the basis of the number of filling yarns per inch:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

Percale
Muscale
Unnamed
Muslin { Grade *A*
Grade *B*
Grade *C*

Physical Properties

4. Bleached wide cotton sheeting shall conform to the requirements specified in Table I.

Methods of Testing

5. (*a*) All test procedures, except as specified in Paragraph (*b*), shall be in accordance with the Standard General Methods of Testing Woven Textile Fabrics. (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

(*b*) *Sizing.*—The amount of sizing material shall be determined in accordance with Section 3 of the Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (A.S.T.M. Designation: D 276 - 37 T) of the American Society for Testing Materials.[2]

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 220.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1174 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1407.

TENTATIVE SPECIFICATIONS
FOR
TERRY (TURKISH) TOWELING[1]

A.S.T.M. Designation: D 505 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications apply to all-over looped terry (Turkish) toweling.

Nature of Material Covered

2. Terry toweling shall be a cotton fabric covered with loops on both sides, constructed with a set of ground warp yarns either single or double ply, a set of warp pile yarns and a set of filling yarns and having not less than 22 yarns per inch in the ground and 26 yarns per inch in the pile and in the filling, a breaking strength (raveled strip method) of not less than 18 lb. warpwise and 30 lb. fillingwise, and weighing not less than 8 oz. per sq. yd.

TABLE I.—PHYSICAL PROPERTIES OF TERRY TOWELING (FINISHED).

		Type 1	Type 2	Type 3	Type 4
Warp yarn (ground), ply		single	single	double	double
Count, min., yarns per in.	Ground warp	22	26	26	30
	Pile	44	26	52	30
	Filling	26	30	32	34
Weight, min., oz. per sq. yd.		8	8	10	11
Breaking strength, min., lb. (raveled strip test)	Warp	18	26	34	44
	Filling	30	30	34	34

Classification

3. Terry toweling shall be classified in the following types on the basis of the ply of the ground warp yarns and the ratio of the number of pile yarns per inch to the number of ground warp yarns per inch:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

	PLY OF GROUND WARP YARNS	RATIO OF PILE TO GROUND WARP YARNS
Type 1	single	2 to 1
Type 2	single	1 to 1
Type 3	double	2 to 1
Type 4	double	1 to 1

Physical Properties

4. Terry toweling shall conform to the requirements specified in Table I.

Methods of Testing

5. All test procedures shall be in accordance with the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

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[1] 1938 Supplement to Book of A.S.T.M. Standards, p. 220.

TENTATIVE METHOD OF TEST

FOR

FASTNESS OF COLORED TEXTILE FABRICS TO LIGHT[1,2]

A.S.T.M. Designation: D 506 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method of test is applicable to all colored fabrics and deals with the fastness of the color to sunlight or artificial light.

Test Specimens

2. (*a*) One or preferably two test specimens shall be cut from the piece of fabric to be tested, and the same number of specimens from each standard dyeing which is to be used for purposes of classification.

(*b*) Each test specimen shall measure about 2½ by 3 in., the longer dimension running in the direction of the warp.

(*c*) Each test specimen shall be placed between opaque covers or in a holder which will shield it from the light except for an area of about 1½ by 1¾ in.

Standard Dyeings

3. The following standard dyeings on wool shall be used for the classification of light fastness:

L1	0.8 per cent Brilliant Wool Blue FFR Extra,
L3	1.2 per cent Brilliant Indocyanine 6B,
L5	0.83 per cent Cyananthrol RXO, and
L8	3.0 per cent Indigosol Blue AGG.

NOTE.—These standard dyeings are obtainable from the Secretary of the American Association of Textile Chemists and Colorists, Mr. H. C. Chapin, Lowell Textile Inst., Lowell, Mass.

Apparatus

4. (*a*) *Sunlight Test.*—The test specimens shall be mounted in a cabinet covered with a good grade of window glass about ⅛ in. in thickness, and open at the sides to allow free access of air to the specimens. The distance between the specimens and the glass shall not be less than ½ in. The glass shall be kept well cleaned. The cabinet shall be mounted on the roof or

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] This tentative method of test conforms in substance, but not in form, with the method developed by the Research Committee of the American Association of Textile Chemists and Colorists.

in any location free from shadows so that the specimens will be exposed at an angle of 45 deg. from the horizontal, facing due south. The exposures shall be made between the hours of 9 a. m. and 3 p. m. on sunny days and during the period of the year from April 1 to October 1.

(*b*) *Artificial Light Test.*—The test specimens shall be exposed in the type FDA Fade-Ometer or its equivalent. A suitable fading lamp shall consist of a carbon arc enclosed in Pyrex glass, operated on a direct current of approximately 13 amp. with 140 v. across the arc. The voltage of the power line shall be 208 to 250 v. The distance from the arc to the test specimen shall be 10 in. The air about the test specimens during exposure shall be humidified, but not to exceed 50 per cent relative humidity. The temperature of the air in the vicinity of the specimens shall not exceed 105 F. (40 C.) during the test.

Method of Test

5. The test specimens shall be exposed simultaneously in the sunlight test or the artificial-light test until the fabric being tested has faded slightly. One of the two specimens of the test fabric and one of each of the standards shall be then set aside and the exposure of the others shall be continued for an equal period of time. If only one specimen of the test fabric is used, one-half of the exposed area shall be covered with an opaque material and the other half shall then be exposed for a total time twice that of the first. After the exposure the specimens shall be allowed to lie in the dark at room temperature for at least 2 hr. before classifying the light fastness of the test fabric.

Classification of Fastness of Color

6. (*a*) The classification of the light fastness of the test fabric shall be determined by a visual comparison of its change in color with the change in color of the standards. The amount of fading shall be judged by comparing the exposed and adjacent unexposed areas of each test specimen under daylight ranging from average daylight to that of a slightly bluish north sky (Note), or under equivalent artificial daylight.

NOTE.—Average daylight is considered to approximate 6500° Kelvin in color temperature, and slightly bluish north-sky not more than 8500° Kelvin.

(*b*) The following classes of fastness to light of all colored fabrics when tested in accordance with Section 5 shall be distinguished by comparison with the standard dyeings (Section 3) under the light specified in Paragraph (*a*):

Class 0.—Fabrics which show a greater change in color than standard L1.

Class 1.—Fabrics which show no greater change in color than standard L1.

Class 3.—Fabrics which show no greater change in color than standard L3.

Class 5.—Fabrics which show no greater change in color than standard L5.

Class 8.—Fabrics which show no greater change in color than standard L8.

TENTATIVE GENERAL METHODS OF TESTING AND TOLERANCES

FOR

SPUN RAYON YARNS AND THREADS[1]

A.S.T.M. Designation: D 507 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa

ISSUED, 1938.

Scope

1. These methods of testing and tolerances apply to spun rayon yarns, both single and plied, and to spun rayon threads.

DEFINITIONS

Spun Rayon

2. Yarn spun from rayon staple.

Yarn Number

3. The number of a spun rayon yarn or the equivalent single number of a plied yarn or thread shall be the number of thousands of yards per pound (typp system).

NOTE 1.—The number may also be expressed as the number of 840-yd. hanks per pound if the yarn is spun by the cotton or spun-silk system, or 560-yd. hanks per pound if spun by the worsted system.

NOTE 2.—The equivalent single number of a plied yarn or thread may be calculated by dividing the yarn number of the single yarns or threads by the number of plies. For example, a two-ply yarn made from No. 20 single yarns has an equivalent single number of 10.

Direction of Twist

4. The direction of twist shall be as defined in the Tentative Definitions and Terms Relating to Textile Materials (A.S.T.M. Designation: D 123-38 T) of the American Society for Testing Materials, as follows:

Twist, Direction of.—A yarn or cord has **S** twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and **Z** twist if the spirals conform in slope to the central portion of the letter "Z."

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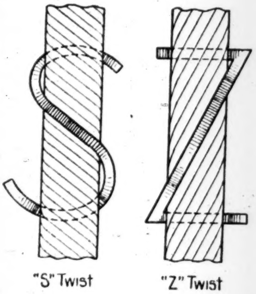
[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.



Standard Condition

5. (*a*) *Standard Condition.*—Standard condition of spun rayon yarn or thread shall be that reached by the yarn or thread when in moisture equilibrium with a standard atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.). A tolerance of ±2 per cent is permitted in relative humidity and ±2 F. (±1.1 C.) in temperature.

(*b*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when, after free exposure to air in motion, there is no progressive increase in weight. Moisture equilibrium shall be approached from the dry side (not moisture free).

Moisture Regain

6. *Standard Regain.*—The commercial moisture regain for spun rayon yarn or thread made from cuprammonium, viscose, or nitrocellulose staple shall be 11 per cent of the oven-dry weight, and when made from acetate staple shall be 6.5 per cent of the oven-dry weight of the yarn.

Tolerances

7. Tolerances are the limits within which the specified characteristics of the yarn or thread must come to constitute a good delivery on contract.

TOLERANCES

Yarn Number

8. The average number of the spun rayon yarn, either single or plied, in each carton or case of skeins, tubes, spools, cops, pirns, cones, or a beam warp as determined by test, shall not vary more than 5 per cent over or under the specified number.

Breaking Strength

9. The average breaking strength of the yarn or thread in each carton, case, bale, chain ball, or beam warp, shall be not less than the specified breaking strength.

Direction of Twist

10. The direction of twist shall be **S** or **Z**, as specified.

Twist

11. The average turns per inch of twist of the yarn in each carton, case, bale, chain ball, or beam warp, shall not be more than 5 per cent over or under the specified twist.

NOTE: *Example.*—A twist of 20 turns per inch is specified; tolerances would allow a twist of 19 to 21 turns per inch.

METHODS OF TESTING

Test Conditions

12. The yarn or thread shall be brought to a standard condition (Section 5 (*a*)) prior to testing and tests shall be made under the standard atmospheric conditions.

Breaking Strength, Preferred Method, Single Strand

13. (*a*) *Preparation.*—The single strand shall be drawn from the package directly as required for testing and shall be drawn from the side of the package in order to avoid disturbing the twist. If the yarn or thread has been wound previously in a skein, the latter shall be mounted on an umbrella reel from which the single end can be drawn. If the yarn or thread is on beams, skeins shall be reeled as described in Section 14 (*a*) and (*c*) and placed on an umbrella reel for testing.

(*b*) *Testing Machine.*—All single strands shall be broken on an approved type of testing machine of suitable capacity. The distance between clamps shall be 10 ± $\frac{1}{16}$ in. The free end of the single strand shall be gripped in the upper clamp of the machine. The yarn or thread shall then be gripped in the lower clamp. Care shall be taken that no twist is lost in preparing the specimen either by the yarn untwisting or by the twist running back into the yarn below the lower clamp before the nip is set. The speed of the pulling clamp shall be 12 ± $\frac{1}{2}$ in. per min. If the yarn breaks at the clamp of the testing machine, the results shall be discarded.

(*c*) *Number of Tests.*—Four tests shall be made on each of 10 packages of yarn or thread from every carton, case or bale and the average of these 40 tests shall be the average strength of the yarn or thread in the carton, case or bale; 4 tests shall be made on each of 4 ends in a beam warp and the average of these 16 tests shall be the average strength of the yarn or thread in the beam warp.

Breaking Strength, Alternate Method, Skein

14. (*a*) *Reel.*—Any yarn reel having a 1$\frac{1}{2}$-yd. perimeter may be used in preparing the skeins.

(*b*) *Preparation from Packages.*—For yarns or thread wound on bobbins, cops, cones, or small flanged spools, the yarn or thread shall be drawn from the top of the package at a speed of 100 to 300 r.p.m. of the reel. If the reel has only one pigtail guide, tension shall be applied by taking one full wrap around the guide. If the reel has two or more guides, the yarn shall pass straight through the guides onto the reel, the angles of the guide supplying the necessary tension. For yarns or threads on parallel tubes and large flanged spools, the yarn or thread shall be drawn from the side at a speed of 20 to 30 r.p.m. of the reel. If the reel has one, two, or more guides, the yarn or thread shall pass straight through onto the reel. Judgment must be used in applying tension on yarns or threads having a small or large amount of twist. The skeins of yarn or thread, both single and plied and both single and multiple wound, in packages shall be reeled in accordance with the following table. The finishing end of the skein shall be tied to the starting end of the skein in a square knot.

NUMBER OF ENDS IN THE PACKAGE	YARDS TO REEL FOR TEST	YARDS IN SKEIN
1	120	120
2	60	120
3	45	135
4 and 5	30	120 and 150
6 and 7	20	120 and 140
8 and above	15	120 and above

(*c*) *Preparation from Beams.*—When the yarn or thread is on beams, the skeins shall be prepared in the following manner: Place the beam containing the yarn or thread to be tested on two bearings sufficiently high from the floor so that the beam can be turned easily. Directly in front of the beam and at least 15 ft. from the beam, place a small table, the top of which is approximately the same height as the top of the beam of yarn or thread. On this table place a standard yarn reel. Attach a small crank arm to one end of the beam shaft. Four ends of yarn or thread from the beam shall be fastened to the yarn reel in the same manner as in testing yarn or thread from bobbins. One operative shall turn the beam slowly in such a direction that the yarn will unwind and a second operative shall turn the reel fast enough to take up the yarn as it comes from the beam. The operation shall be continued until 120 yd. are taken from the beam.

NOTE.—In using beams after the test ends have been removed, a set of spools containing the same kind of yarn or thread as that on the beam may be placed behind the beam on a small creel to replace the ends that have been used for testing. When the ends which supplied the test skeins come up on the beam, the auxiliary spools may be broken out.

(*d*) *Testing Machine for Skein Tests.*—All skeins shall be broken on an approved pendulum type of automatic power yarn tester of 150 and 300-lb. capacities. The lower capacity shall be used until the swing of the pendulum exceeds an angle of 45 deg. from the vertical. The higher capacity shall be used for yarns or threads breaking above this point. The spools used for holding the skeins shall be not less than 1 in. in diameter, and not less than 1 in. in width so supported that at least one spool can turn freely on its axis. The distance between the spools shall be sufficient to permit placing the skeins on the spools in a wide flat band with as little disturbance after reeling as possible. The speed of the pulling spool shall be 12 ± ½ in. per min.

(*e*) *Number of Skein Tests.*—Three tests shall be made on each of four packages of yarn or thread from every case or bale and the average of these twelve tests shall be the average breaking strength of the yarn or thread in the case or bale; one test shall be made on each of four ends in a beam and the average of these four tests shall be the average breaking strength of the yarn or thread on the beam.

Breaking Strength, Correction to Specified Number

15. The average breaking strength shall be corrected to the specified yarn number by the following formula:

$$T = \frac{S \times N}{Y}$$

where T = the breaking strength corrected to specified number,
S = the actual average breaking strength,
N = the actual average yarn number, and
Y = the specified yarn number.

NOTE.—The actual average yarn number shall be determined in accordance with Section 16.

Yarn Number

16. (*a*) *Single Strand.*—If the breaking strength determination is made by the single strand test, 120-yd. skeins shall be reeled from each test package as prescribed in Section 14 (*b*) except for single yarn on beams and all plied yarns which shall be reeled in accordance with the following table:

TYPE OF YARN OR THREAD	EQUIVALENT SINGLE NUMBER			YARDS TO REEL FOR TEST
	TYPP SYSTEM	COTTON SYSTEM	WORSTED SYSTEM	
Single yarn on beams				60
All plied yarns	16.8 and above	20 and above	30 and above	60
	2.5 to 16.8	3 to 20	4.5 to 30	24
	Below 2.5	Below 3	Below 4.5	12

(*b*) *Skein.*—If the breaking strength determination is made by the skein test, then all skeins shall be weighed immediately after breaking.

(*c*) *Weighing Balance.*—The balance used for weighing shall be accurate to 0.25 per cent of the number of the yarn under test and may indicate the yarn number directly. If the number is indicated directly, the scale readings for skeins of multiple-wound yarns containing more than 120 yd. (see table, Section 14 (*b*)) shall be reduced by proper ratio to a 120-yd skein basis.

(*d*) *Calculation.*—The yarn number shall be calculated from the weight and yardage of the skein by the following formula:

$$n = \frac{l}{w} \times \frac{7000}{L}$$

where n = the yarn number,

l = the length of single or plied yarn in yards,

w = the weight in grains,

L = the yards of No. 1 yarn in 1 lb., and

7000 = the grains in 1 lb.

NOTE.—L = 1000 for typp system, 840 for cotton or spun silk system, and 560 for worsted system.

(*e*) *Number of Tests.*—Where skeins are already available from the breaking strength test, these same skeins shall be used, namely, three from each of four packages. Where it is necessary to reel skeins from packages, one test shall be made on each of 10 packages. Where the yarn is on beams, one test shall be made on one end. The average of these results shall be the average number of the yarn in each carton, case, bale, chain ball, or beam warp.

Twist

17. (*a*) *Direction of Twist.*—The direction of twist shall be determined in accordance with Section 10.

(*b*) *Turns per Inch, Single Yarn or Thread.*—The turns per inch of twist in single yarn or thread shall be determined on any standard single yarn twist tester employing the principle of first taking the twist out of a given length of yarn and then retwisting in the opposite direction until the same amount of twist is put back, dividing the results by twice the distance between clamps to obtain the twists per inch. The minimum distance between clamps shall be 5 in., but a 10-in. distance is preferable. In making this test, it is essential that check tests be made before proceeding with regular tests in order to determine the proper tension to be placed on the yarn or thread so as not to cause slippage of the fibers and other variations.

(*c*) *Turns per Inch, Plied Yarn or Thread.*—The turns per inch of twist in plied yarn or thread shall be determined on any standard twist counter with clamps set 10 in. apart. The strand shall be fastened in the clamps under a definite tension by applying a load in grams equal to 131 divided by the yarn or thread number.

NOTE.—In the case of plied yarns, the equivalent single number Section 3 shall be used. The constant 131 represents the tension which will straighten, without stretching, a No. 1 (typp system) yarn or thread. The constant becomes 156 if the cotton or spun silk system is used, and 233 if the worsted system is used.

(*d*) *Number of Tests, Single Yarn or Thread.*—Three twist tests on each of 10 packages of single yarn or thread from each carton, case or bale shall be made, and the average of these 30 tests shall be the average twist of the yarn or thread in the case or bale. If the yarn or thread is in chain ball or beam warp form, at least 30 tests shall be made per unit.

(*e*) *Number of Tests, Plied Yarn or Thread.*—Three twist tests on each of 4 packages from each carton, case or bale shall be made and the average of these 12 tests shall be the average twist of the yarn in the case or bale. If the yarn is in chain ball or beam warp form, at least 12 tests shall be made per unit.

Tentative Method of Test for

FIBER LENGTH OF WOOL[1]

A.S.T.M. Designation: D 519 - 38 T

Issued, 1938.

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for estimating the fiber length of wool in loose form, top, or roving. It is also applicable to other fibers.

Fiber Length

2. The fiber length of wool determined in accordance with this method shall be expressed in terms of the arithmetic mean in inches and tenths of an inch. The distribution of length shall be expressed by the standard deviation or by a frequency or cumulative frequency curve.

Condition

3. (*a*) *Standard Condition.*—The standard condition of fibers shall be that reached when in moisture equilibrium with a standard atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.). A tolerance of plus or minus 2 per cent is permitted in relative humidity and plus or minus 2 F. (1.1 C.) in temperature.

Note.—These permissible variations from standard condition will cause a difference in length of less than 1 per cent.

(*b*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when two successive weighings made not less than 15 min. apart show not more than 1 per cent change in weight.

Test Condition

4. All fibers shall be tested under standard condition as described in Section 3(*a*), unless otherwise specified.

Apparatus

5. (*a*) *Stapler.*—A stapling machine, similar to that illustrated in Fig. 1, shall be used. It shall be capable of segregating the longer fibers into ½-in. groups and the shorter fibers into ¼-in. groups. It consists of the following essential parts: A frame, *1*; a series of fifteen parallel "faller" bars, *2*, each pivoted at one end and fitted with a set of long needles at *2a* and a set of short needles at *2b*, so arranged that the first five bars are spaced ¼ in. on centers followed by ten bars spaced ½ in. on centers; a re-

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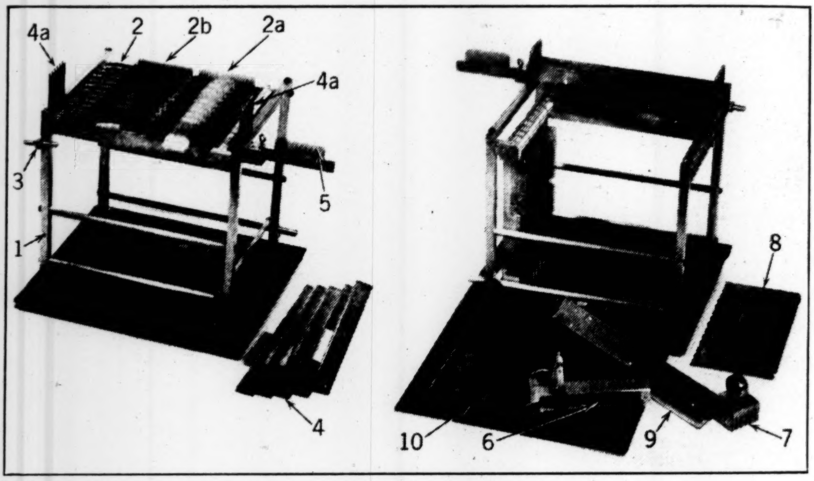
[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

movable supporting rod to permit dropping the bars out of position one at a time, *3*; a series of removable retaining bars, *4*, held in position by racks, *4a*; a small combing bar, *5*, attached to the front of the machine; an adjustable drawing clamp, *6*; a fiber depressor, *7*; a faller bar lifting plate, *8*; a ruler, *9*, for measuring the length of fibers when laid out on the plush board, *10*.

(*b*) *Balance.*—A balance weighing to 0.1 mg. shall be used.



Position for Procedure Described in Section 7 (*a*)

Position for Procedure Described in Section 7 (*b*)

FIG. 1.—Wool Fiber Stapling Apparatus.

NOTE.—The method here described is especially adapted to the Suter wool fiber stapling apparatus, but with more or less obvious alteration in procedure may be carried out with two Baer or two Zweigle sorters, or any other similar sorters provided with two banks of combs.

Sampling

6. For loose scoured wool, random selections from the lot to be tested shall be processed for a thorough mixing. From the sliver produced, or from top or roving, specimens shall be taken from at least five distributed areas to form the sample. The sample, with fibers generally parallel, shall be at least 2 ft. in length and not in excess of $1\frac{1}{2}$ in. in width.

Procedure

7. (*a*) The small combing bar shall be swung out and locked, and the retaining bars lifted from their positions. The prepared sample shall be placed upon the section of combs with the longer needles and pressed down with the depressor. The width of the sample in the combs shall not exceed $1\frac{1}{2}$ in. in order that it may be easily handled by the drawing clamp. Projecting fibers shall be pulled out by means of the clamp until the sample has an even edge extending 1 in. beyond the first faller bar. The fibers across the full width of the bundle shall be firmly gripped by means of the drawing clamp to a depth not exceeding $\frac{1}{16}$ in. from their ends, drawn out and passed twice through the small combing bar. The fibers remaining in the clamp shall then be drawn through the combs with the shorter needles until the clamped ends of the fibers reach the front faller bar. The fibers shall then

be released and pressed down into the needles with the depressor. Care should be taken to have the released ends of the fibers as close to the front faller bar as possible. The drawing, combing, and placing of fibers shall be repeated until a bundle of fibers that will weigh from 0.5 to 1.0 g. has been accumulated. The original sliver shall then be removed. The retaining bars that had been removed shall be placed in position with their needles projecting downward into the fiber bundle.

TABLE I.—ILLUSTRATIVE FORM FOR RECORDING TEST DATA AND CALCULATING THE AVERAGE FIBER LENGTH OF WOOL, THE STANDARD DEVIATION AND COEFFICIENT OF VARIATION.

Class Intervals, in.	Weight, g.	Percentages	Cumulative Frequencies	
			First Cumulative Less Than	Second Cumulative Less Than
6.0 to 6.5	0.014	2.4	100.0	840.1
5.5 to 6.0	0.010	1.7	97.6	740.1
5.0 to 5.5	0.013	2.2	95.9	642.5
4.5 to 5.0	0.018	3.1	93.7	546.6
4.0 to 4.5	0.038	6.5	90.6	452.9
3.5 to 4.0	0.051	8.7	84.1	362.3
3.0 to 3.5	0.062	10.6	75.4	278.2
2.5 to 3.0	0.072	12.3	64.8	202.8
2.0 to 2.5	0.079	13.5	52.5	138.0
1.5 to 2.0	0.080	13.6	39.0	85.5
1.0 to 1.5	0.065	11.0	25.4	46.5
0.5 to 1.0	0.045	7.7	14.4	21.1
0 to 0.5	0.039	6.7	6.7	6.7
Totals ...	0.586	100.0 = n	840.1	4363.3
	Divided by n....		$F_1 = 8.40$	$F_2 = 43.63$

B = the largest midpoint value for which a frequency is recorded = 6.25
m = the class interval = 0.5

Calculations:

$$\bar{X} = B - m(F_1 - 1) = 6.25 - 0.5(8.40 - 1) = 2.6 \text{ in.}$$

$$\sigma = m\sqrt{2F_2 - F_1 - F_1^2} = 0.5\sqrt{87.26 - 8.4 - 71.0} = 1.4 \text{ in.}$$

$$v = 100\frac{\sigma}{X} = 100 \times \frac{1.4}{2.6} = 53.8 \text{ per cent}$$

where X = the average fiber length of wool,
σ = the standard deviation, and
v = the coefficient of variation.

(*b*) The distribution of length shall be determined by the following procedure: Working from the rear of the machine, drop all faller bars not containing fibers. All fibers projecting beyond the next bar shall be drawn out and placed on it in the form of a ball. This bar shall then be dropped by pulling out the supporting rod. This process shall be continued with each bar located at 1-in. and $\frac{1}{2}$-in. intervals. Faller bars located at $\frac{1}{4}$-in. intervals shall be dropped as reached without drawing fibers projecting beyond them. The retaining bars shall be removed as reached. After all fibers have been drawn out and balled, all bars shall be raised. The balls shall be removed with tweezers, and the weight of each ball in milligrams shall be determined and recorded on the form (Table I) opposite its proper length interval.

Calculations

8. The illustrative form given in Table I is recommended for recording the test data and calculating the average fiber length of wool, the standard deviation and coefficient of variation.

TENTATIVE METHODS OF TESTING AND TOLERANCES
FOR
YARNS SPUN FROM WOOL MIXED WITH FIBERS OTHER THAN WOOL[1]

A.S.T.M. Designation: D 508 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These methods of testing and tolerances apply to single or plied yarns of any of the following types spun from wool mixed with fibers other than wool:

(*a*) *Yarns Spun on the Woolen System:*

- *Scoured Spun-in-Oil Yarn*, made from thoroughly scoured wool to which oil has been added,
- *Semiscoured Spun-in-Oil Yarn*, made from wool which has been washed at the source but not scoured, and to which oil has been added, and
- *Dry-Spun Yarn*, made from thoroughly scoured wool without the addition of oil.

(*b*) *Yarns Spun on the Worsted System:*

- *Spun-in-Oil or Dry-Spun Yarn*, either French or Bradford System.

(*c*) *Yarns Spun on the Cotton System:*

- *Combed Yarn*, made from combed sliver, and
- *Carded Yarn*, made from carded sliver.

Material and Workmanship

2. The yarn shall be reasonably clean and free from slubs and shall be reasonably uniform in diameter in view of the purpose for which it is to be used.

Packing and Marking

3. Each case, beam, or other package of yarn shall be plainly marked with the name of the seller, the net and gross weights and some means of identifying the contracts under which it was delivered.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

Weight of Shipment

4. The net weight of the shipment of yarn shall be calculated to the basis of standard regain.

Extractable Matter, Total

5. The total extractable matter (standard regain basis) shall not exceed the following requirements:

(*a*) *Woolen System.*—Scoured, spun-in-oil yarn shall contain not more than 7 per cent of extractable matter; semi-scoured, spun-in-oil yarn, not more than 15 per cent of extractable matter; and dry-spun yarn, not more than 2 per cent of extractable matter.

(*b*) *Worsted System.*—Dry-spun yarns shall contain not more than 1.5 per cent of extractable matter, and oil-spun yarns not more than 4 per cent of extractable matter.

DEFINITIONS

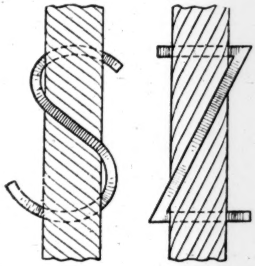
Yarn Number

6. The number of a yarn spun from wool mixed with fibers other than wool shall be the number of thousands of yards per pound (Typp system).

Direction of Twist

7. The direction of twist shall be as defined in the Tentative Definitions and Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 – 38 T) of the American Society for Testing Materials, as follows:

Twist, Direction of.—A yarn or cord has **S** twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and **Z** twist if the spirals conform in slope to the central portion of the letter "Z."



Standard Condition

8. (*a*) *Standard Condition.*—Standard condition of a yarn spun from wool mixed with fibers other than wool shall be that reached by the yarn when in moisture equilibrium with a standard atmosphere having a relative

humidity of 65 per cent at 70 F. (21 C.). A tolerance of ± 2 per cent is permitted in relative humidity and ± 2 F. (1.1 C.) in temperature.

(*b*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when two successive weighings not less than 15 min. apart show not more than 1 per cent change in weight.

Moisture Regain

9. (*a*) *Standard Regain, Fiber.*—The following values shall be used as the standard moisture regains for the respective fibers:

FIBER	MOISTURE REGAIN PER CENT
Cotton	7.5
Rayon, acetate	6.5
Rayon, other than acetate rayon	11.0
Silk	11.0
Woolen	13.0
Worsted, dry spun	15.0
Worsted, oil spun	13.0

(*b*) *Standard Regain, Mixed Yarn.*—The standard regain of a yarn spun from wool mixed with fibers other than wool shall be that calculated from the standard regains of the fibers used in proportion to the percentage composition based on the dry fiber content by means of the following formula:

$$\text{Standard regain, per cent} = \frac{(A \times R_a) + (B \times R_b) + \ldots .(N \times R_n)}{100}$$

where $A, B, \ldots\ldots N$ = percentage (dry basis) of fibers $a, b, \ldots n$, respectively, and

$R_a, R_b, \ldots R_n$ = percentage of standard regains of fibers $a, b, \ldots n$, respectively.

NOTE: *Example.*—The standard regain of a yarn spun from 40 per cent worsted and 60 per cent cotton (dry spun, French system) is calculated as follows:

$$\text{Standard regain, per cent} = \frac{(40 \times 15) + (60 \times 7.5)}{100} = 10.5$$

Tolerances

10. Tolerances are the limits within which the specified characteristics of the textile must come to constitute a good delivery on contract.

TOLERANCES

11. Yarn spun from wool mixed with fibers other than wool shall conform to the tolerances prescribed in Sections 12 to 15. When averages are used the number of tests shall be reported and the standard deviation or some other method of dispersion indicated.

Yarn Number

12. The average yarn number shall be as specified within the following permissible variations:

YARNS SPUN ON WOOLEN SYSTEMS		PERMISSIBLE VARIATIONS, PER CENT
Single Yarns	Coarser than No. 3	±12
	Nos. 3 to 6	±10
	Nos. 6 and finer	±7.5
Plied Yarns		±5

YARNS SPUN ON WORSTED OR COTTON SYSTEM		PERMISSIBLE VARIATIONS, PER CENT
Single Yarns	Coarser than No. 12	±7.5
	Nos. 12 to 17	±5
	Nos. 17 to 23	±4
	No. 23 and finer	±3.5
Plied Yarns		±2.5

Breaking Strength

13. The breaking strength of yarn shall be not less than that specified.

Direction of Twist

14. The direction of twist shall be **S** or ***Z*** as specified.

Twist

15. The average twist of yarn from all the packages tested shall not be more than 7.5 per cent over or under the specified twist. The average twist of yarn from any one package shall not be more than 7.5 per cent over or under the average for any other package in the shipment.

METHODS OF TESTING

Test Condition

16. All yarns shall be tested under standard condition as described in Section 8.

Sampling

17. (*a*) Samples shall be so selected as to be representative of the shipment.

(*b*) For yarn on cones, spools, or bobbins, seven cones, spools, or bobbins shall be selected from each case of yarn.

(*c*) For yarn on beams each beam of yarn shall be tested separately.

Preparation of Skeins

18. Standard skeins of 120 yd. shall be prepared by winding the yarn on a reel having a perimeter of 1½ yd. Care must be used to maintain uniform tension. The yarn shall make one full turn around single guides or pass straight through double guides. It is preferable to equip yarn reels with motors.

Yarn Number

19. Standard skeins shall be weighed to an accuracy of 0.25 per cent and the yarn number calculated. The yarn number shall be the arithmetic mean of the results.

Breaking Strength

20. (*a*) *Skein Method.*—Conditioned skeins shall be broken on an approved type of testing machine. The device for holding the skeins shall be cylindrical spools not less than 1 in. in diameter and not less than 1 in. in length, so supported that at least one can turn freely on its axis. The speed of the pulling spool when running free shall be 12 ± ½ in. per min. The average skein breaking strength shall be the arithmetic mean of the results.

(*b*) *Single-Strand Method.*—Conditioned single strands shall be broken on an approved type of testing machine, with clamps set 10 in. apart. The speed of the pulling clamp when running free shall be 12 ± ½ in. per min. The average single strand breaking strength shall be the arithmetic mean of the results.

Twist

21. (*a*) *Direction of Twist.*—The direction of twist shall be determined in accordance with Section 7.

(*b*) *Turns per Inch, Single Yarns.*—The first 2 yd. of any package of yarn shall be discarded. The yarn, drawn just taut enough to prevent sagging, shall be gripped in a twist counter with clamps set 4 in. apart. One clamp shall be rotated until the twist is removed as indicated by passing a sharp pointed needle from clamp to clamp. Not more than ½ in. of yarn shall be left out between individual tests. The twist of the yarn in a shipment shall be the average of 80 tests made on 20 continuous lengths of each of 4 strands. Care must be taken that the yarn is drawn from the side of a package of yarn and also that it is not twisted or untwisted while handling.

(*c*) *Turns per Inch, Plied Yarns.*—The twist of plied yarns shall be determined as described in Paragraph (*b*) with the following exceptions: The clamps shall be set 10 in. apart and a tension equal to the weight of 100 yd. of yarn shall be applied. The twist of the yarn in a shipment shall be the average of 40 tests made on 10 continuous lengths of each of 4 strands.

Extractable Matter

22. (*a*) *Ether Extract.*—Three 10-g. samples (approximate) shall be extracted separately in a Soxhlet apparatus for 20 extractions with alcohol-free ethyl ether (Note). In the bottom of the Soxhlet apparatus there shall be lightly placed a thin layer of cotton, previously extracted with ethyl ether, as a filter covering the opening of the siphon tube. The ether

shall then be evaporated from the extract and the residue dried to constant weight at 100 to 105 C. This residue is ether extract.

NOTE.—C.p., carbon tetrachloride shall be substituted for ethyl ether for Code work.

(*b*) *Alcohol Extract.*—The samples from which the ether extract has been removed (Paragraph (*a*)) shall be extracted in a Soxhlet apparatus for 12 extractions with neutral 95 per cent alcohol. The alcohol shall then be evaporated from the extract and the residue dried to constant weight at 100 to 105 C. This residue is alcohol extract.

(*c*) *Weight, Oven-Dry Extracted Yarn.*—The extracted yarn (Paragraph (*b*)) shall be dried to constant weight at 105 to 110 C.

(*d*) *Calculations.*—The percentage of ether extract and of alcohol extract may be calculated on a dry or a standard regain basis by the following formulas:

$$\text{Ether extract (dry basis), per cent} = \frac{E \times 100}{W + E + L}$$

$$\text{Alcohol extract (dry basis), per cent} = \frac{L \times 100}{W + E + L}$$

$$\begin{array}{l}\text{Ether extract, per cent}\\ \text{(standard regain basis)}\end{array} = \frac{E \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + E + L)}$$

$$\begin{array}{l}\text{Alcohol extract, per cent}\\ \text{(standard regain basis)}\end{array} = \frac{L \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + E + L)}$$

where E = the weight of ether extract,
L = the weight of alcohol extract, and
W = the weight of oven-dry extracted yarn.

(*e*) Three samples shall be tested from each case or beam of yarn. If the three determinations do not check, or if the average results fail to conform to the requirements specified in Section 5, three additional samples shall be tested from the same case or beam from which the original samples were taken.

Determination of Wool Content

23. (*a*) Before proceeding with the quantitative analysis of fiber content, microscopical examination shall be made to determine the various types of fibers used in the mixed yarn. Wherever possible a mechanical separation should be made and the amount of each kind of fiber calculated on a weight percentage basis.

(*b*) When a chemical analysis is necessary because of inter-mixing of fibers, the analysis shall be made in accordance with Sections 3 to 9 of the Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (A.S.T.M. Designation: D 276 - 37 T) of the American Society for Testing Materials.[1]

Regain Determination

24. (*a*) Three samples of not less than 200 g. each shall be so selected that they represent the bulk of the shipment. These samples shall be weighed at the same time and under the same conditions as the bulk of the yarn. The samples shall then be placed in a conditioning oven at a temperature of 220 to 230 F. (105 to 110 C.). When in three consecutive weighings at 10-min. intervals the change in weight is not more than 0.1 per cent, the yarn shall be considered "oven dry." The final weight is the oven-dry weight.

(*b*) The difference between the original (initial)weight and the oven-dry weight of each of the three samples shall be calculated and the average of these results considered as the "moisture loss."

(*c*) The percentage moisture regain equals the moisture loss multiplied by 100 and divided by the average oven-dry weight.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1174 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1407.

TENTATIVE METHODS OF TESTING WOOL FELT[1]

A.S.T.M. Designation: D 461 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1937; Revised, 1938.

Scope

1. These methods of test are applicable to fabrics which are neither woven nor knitted, but built up by the interlocking of wool fibers by mechanical work, chemical action, moisture, and heat. Felt may be produced by one or a combination of any of these factors. It may consist of wool, or wool mixed with other fibers, or fibers other than wool.

Standard Condition

2. (*a*) Standard condition of a felt shall be that reached by the fabric in moisture equilibrium in an atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.). A tolerance of ±2 per cent is permitted in relative humidity and ±2 F. (1.1 C.) in temperature.

(*b*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when two successive weighings not less than 30 min. apart show not more than 1.0 per cent change in weight.

Test Condition

3. All felts shall be tested under standard conditions as described in Section 2.

Methods of Physical Testing

Length

4. The length of a roll or piece shall be determined by running the felt over a measuring drum of known circumference, from which the yardage is registered by a dial or counter driven by a chain, or other positive non-slip mechanism which measures the length of the back of the felt and is independent of its thickness. Just enough uniform tension shall be used to keep the felt running flat and true. As an optional method, measurement may be made with a steel tape, care being taken to insure that the material lies flat without excess tension.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

Width

5. The width of a roll or piece shall be determined at five different places uniformly distributed along the full length of the roll or piece, and may be determined at the same time as the length.

Thickness

6. (*a*) *Gage.*—The thickness of pieces or sheets shall be measured by a dial micrometer, consisting of an anvil for supporting the specimen, a circular presser foot acting under a dead-weight load, and a dial graduated to read directly in thousandths of an inch.

(*b*) *Supporting Anvil.*—The anvil for supporting the specimen shall have a flat horizontal surface of minimum linear diameter of 2 in. In measuring the thickness of large pieces or sheets of felt, the supporting anvil shall be in the same plane as the supporting table.

(*c*) *Presser Foot.*—The presser foot shall have an area of 1 sq. in. ±0.0025 sq. in. (1.129 in. in diameter). It shall be sufficiently thick to insure rigidity and the edges shall be rounded off with a radius of 0.016 in. ±0.001 in. The surface of the presser foot shall be parallel to that of the supporting anvil.

(*d*) *Load.*—The presser foot shall be actuated by a freely acting total dead-weight load of 10 oz. ±0.5 oz. Less than 0.5 oz. shall be required to overcome friction and to produce perceptible motion of the presser foot when counterbalanced. The load shall be applied gradually and without shock. The thickness reading shall be taken at least 10 sec. after the load is applied.

(*e*) The thickness of cut parts having a minimum linear dimension greater than 1 in. shall be measured by the dial micrometer as prescribed in Paragraphs (*a*) to (*d*).

(*f*) The thickness of cut parts having a minimum linear dimension of 1 in. or less shall be measured by the dial micrometer as prescribed in Paragraphs (*a*) to (*d*) by cutting to fit and closely nesting together a sufficient number of pieces to give a minimum linear dimension of $1\frac{1}{8}$ in. The parts shall not be nested so tightly that they bulge at the cut edges, since this will result in the obtaining of an erroneous reading.

Weight

7. A representative specimen containing not less than 40 sq. in. shall be cut from the felt. The specimen should be taken from midway between the outer edges. No specimen shall be taken within 6 in. of either side or end. The specimen shall be conditioned (Section 2) and then weighed on a balance sensitive to 0.1 per cent of the total weight. The weight shall be expressed in ounces per square yard.

Breaking Strength

8. (*a*) *Testing Machine.*—The breaking strength test shall be made on an approved type of testing machine of proper capacity such as described in the Standard Specifications for Textile Testing Machines (A.S.T.M. Designation: D 76) of the American Society for Testing Materials.[1] The jaws shall not be less than 2 in. in width, and shall be set 3 in. apart. The speed of the pulling jaw shall be 12 ± ½ in. per min.

(*b*) *Test Specimens.*—Specimens for the breaking strength test shall be 2 by 10 in. Eight test specimens, four taken lengthwise and four crosswise of the piece, shall be cut with a die in such a manner that the 10-in. dimension will be parallel to or perpendicular to the length direction, respectively. All specimens shall be conditioned in accordance with Section 2 before testing.

(*c*) *Procedure.*—The breaking strength of each conditioned specimen of felt shall be determined and the average strength in the length and width directions shall be reported separately in pounds per 2-in. width.

Splitting Resistance

9. (*a*) *Testing Machine.*—The splitting resistance shall be determined on a testing machine conforming to the requirements prescribed in Section 8 (*a*).

(*b*) *Test Specimens.*—Specimens for the splitting resistance test shall be 2 by 10 in. Eight test specimens, four taken lengthwise and four crosswise of the piece, shall be cut with a die in such a manner that the 10-in. dimension will be parallel to or perpendicular to the length direction, respectively. All specimens shall be conditioned in accordance with Section 2 before testing.

(*c*) *Procedure.*—The conditioned specimen shall be split in thickness by cutting with a knife within the middle third of the thickness for a distance of approximately 2 in. from one end only. One of these lips shall be clamped in each jaw of the testing machine, the jaws being brought close enough together for the purpose. The machine shall then be started and the average load in pounds necessary to pull the two sections of felt wholly apart shall be recorded as the splitting resistance in pounds. The test results on the four specimens cut lengthwise and the four cut crosswise shall be respectively averaged and reported separately as the splitting resistance in pounds per 2-in. width.

NOTE.—This test is not applicable to felts where the thickness is less than $\frac{3}{16}$ in. For material less than $\frac{3}{16}$ in. in thickness breaking strength only is recommended as an indicative test.

METHODS OF CHEMICAL ANALYSIS

Matter Soluble in Carbon Tetrachloride

10. (*a*) *Sample.*—A sample of approximately 8 g. of the felt shall be prepared for chemical analysis by cutting into pieces approximately ⅛-in. square.

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 241.

(*b*) Approximately 5 g. of the material prepared in accordance with Paragraph (*a*) shall be dried at 105 to 110 C. to constant weight. This shall be designated as the *original oven-dried specimen* and its weight as weight *B*. The original oven-dried specimen shall be extracted with carbon tetrachloride in a Soxhlet apparatus for 4 hr. The carbon tetrachloride shall then be evaporated from the extract and the residue dried at 105 to 110 C. to constant weight. This residue is matter soluble in carbon tetrachloride and shall be reported as a percentage of the weight, *B*, of the original oven-dried specimen.

Matter Soluble in Water

11. The fibrous residue from the carbon tetrachloride treatment (Section 10 (*b*)) shall be dried at 105 to 110 C. to constant weight. It shall then be covered with distilled water and boiled for 15 min. The solution shall be decanted through a filter into a weighed evaporating dish. The boiling with distilled water and decanting shall be repeated four times. The combined solutions shall be evaporated and the residue dried at 105 to 110 C. to constant weight. This residue is matter soluble in water and shall be reported as a percentage of the weight, *B*, of the original oven-dried specimen (Section 10 (*b*)).

Wool Determination

12. In this procedure wool is determined by chemical analysis and not on a *fiber basis*. The fibrous residue from the water extraction (Section 11) shall be dried at 105 to 110 C. to constant weight. This gives the weight of the moisture-free fibrous residue, weight *C*. The moisture-free fibrous residue shall be placed in an Erlenmeyer flask and covered with 105 to 150 ml. of sodium hydroxide solution (5 per cent). A reflux condenser shall then be attached and the solution boiled for 20 min. The undissolved fibers shall be collected on a Gooch filter or a 100 mesh wire screen and washed with distilled water until neutral to litmus paper. The residue shall then be dried at 105 to 110 C. to constant weight. This gives the weight of the vegetable matter, weight *D*. The wool content shall be calculated as a percentage of the weight of the original oven-dried specimen from the following formula:

$$\text{Wool (dry basis), per cent} = \frac{100}{B}\left(C - \frac{D}{0.95}\right)$$

where B = the weight of the original oven-dried specimen (Section 10 (*b*)),
C = the weight of the moisture-free fibrous residue from the water extraction, and
D = the weight of the washed and dried residue (vegetable matter).

NOTE 1.—The above formula is based upon the assumption that 5 per cent of the cotton is dissolved by a sodium hydroxide solution (5 per cent).

NOTE 2.—The wool content may include hair and other animal fibers similar to wool which by hydrolysis are removed with the wool. For detection of substitutes, see Section 14.

Ash

13. The balance (approximately 3 g.) of the material prepared in accordance with Section 10 (*a*) shall be placed in an oven and dried at 105 to 110 C. to constant weight, and allowed to cool in a desiccator. A 2-g. portion of the dried specimen shall be weighed quickly in a tared crucible. The crucible shall be placed in a muffle furnace and the temperature shall be raised slowly to 800 to 1000 C., care being taken to avoid loss of ash by quick ignition or by subjecting the specimen to strong drafts. When all combustible matter has been volatilized, the crucible shall be placed in a desiccator, cooled, and weighed. The ignition and subsequent cooling in a desiccator shall be repeated until a constant weight is obtained. The ash shall be reported as a percentage of the weight of the oven-dried material.

Microscopic Examination

14. In the determination of wool content (Section 12), all animal fibers are included as wool. If it is desired to detect the presence of, and identify, fibers other than wool (such as other animal fibers, vegetable and synthetic fibers), the felt shall be subjected to a microscopical examination such as is described in Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (A.S.T.M. Designation: D 276 – 37 T) of the American Society for Testing Materials.[1]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 1174 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 1407.

TENTATIVE METHODS OF TESTING PILE FLOOR COVERING[1]

A.S.T.M. Designation: D 418 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935; Revised, 1936, 1937, 1938.

Scope

1. These methods of testing are intended to be applicable for testing pile floor coverings.

Sampling

Note.—The size of dissection samples and methods of sampling will be covered in later revisions of these methods.

Condition

2. (*a*) *Unconditioned.*—The weight of the fabric when samples for weight determination are cut from it is the unconditioned weight. A specification of the weight of a fabric must also specify the moisture condition.

(*b*) *Oven-Dry Condition.*—The oven-dry condition of pile fabrics is that state of dryness obtained on equilibrium of the material in a ventilated drying oven maintained at a temperature of 220 to 230 F. (105 to 110 C.).

(*c*) *Standard Condition.*—Standard condition of pile fabric is that reached by the fabric when in moisture equilibrium with a standard atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.). A tolerance of ± 2 per cent is permitted in relative humidity and plus 10 F. (6 C.) in temperature.

(*d*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when, after free exposure to the standard atmosphere in motion, two successive weighings not less than 30 min. apart show not more than 1.0 per cent change in weight. Equilibrium shall be approached from the dry side (not oven dry).

Test Condition

3. All fabrics shall be tested under standard conditions as described in Section 2 (*c*).

Quantity

Length

4. The length of a roll or piece shall be determined by running the fabric over a measuring drum of known circumference, from which the

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

yardage is registered by a dial or counter driven by a chain, or other positive non-slip mechanism. This yardage shall be the length of the fabric and shall be independent of any effect of its thickness.

Width

5. (*a*) The width of a roll or piece shall be determined at five different places uniformly distributed along the full length of the roll or piece, and may be determined at the same time as the total length.

(*b*) Measurements shall be made to the nearest $\frac{1}{16}$ in.

(*c*) The average of the five measurements shall be the width.

Weight

6. (*a*) *Unconditioned Weight.*—Samples in a condition which is the same as the fabric they represent shall be rapidly weighed on a balance sensitive to 0.1 per cent of the total weight. The average of these weights shall be the unconditioned weight of the samples.

(*b*) *Conditioned Weight.*—The samples shall be allowed to come to standard condition as described in Section 2 (*c*). The average of the samples weighed under standard conditions shall be the conditioned weight of the samples and shall be used to calculate the conditioned weight of the fabric.

(*c*) *Oven-Dry Weight.*—One of the samples shall then be converted to the oven-dry condition as described in Section 2 (*b*). This shall be the oven-dry weight of the sample.

Moisture Content and Regain

7. (*a*) *Weight of Moisture.*—The difference between the unconditioned weight (Section 6 (*a*)) and the oven-dry weight (Section 6 (*c*)) shall be the weight of moisture present.

(*b*) *Moisture Content.*—The weight of moisture when calculated as a percentage of the unconditioned weight shall be the "moisture content" of the fabric.

(*c*) *Moisture Regain.*—The weight of moisture when calculated as a percentage of the oven-dry weight shall be the "moisture regain" of the fabric.

Total Thickness

8. Thickness of a fabric shall be determined by measuring to the nearest 0.001 in. the distance between the two plane surfaces of a fabric under a pressure of 0.100 ± 0.001 lb. per sq. in. distributed over a circular area 3.00 in. ± 0.01 in. in diameter. The pressure shall be applied slowly to avoid impact, and the fabric shall be protected from vibration during test. The average of five readings taken at different places, uniformly distributed over the area of the surface, shall be the thickness.

CONSTRUCTION

Back Thickness

9. (*a*) *Procedure.*—The pile yarn shall be removed from a section of the fabric by clipping. A 5-in. diameter metal ring shall be seated on the clipped portion, a flame directed on the area within the ring, and the pile destroyed with alternate charring and brushing without damage to the back construction. The thickness of the remaining back construction shall be determined by measuring to the nearest 0.001 in. the distance between the two plane surfaces of the back construction under a pressure of 0.750 lb. ± 0.001 lb. per sq. in. distribution over a circular area 1.00 ± 0.01 in. in diameter. The pressure shall be applied slowly to avoid impact and the fabric shall be protected from vibration during test. The average of five readings taken at different places within the exposed back construction shall be the back thickness of the sample.

(*b*) *Precision of Test Method.*—Approximately 9 times in 10 a determination of back thickness made in accordance with Paragraph (*a*) would be expected to differ not more than 4 per cent over or under the true average thickness as obtained by a large number of repeat measurements by each of four or more participating independent laboratories.

Net Pile Height

10. The net pile height is the difference between the total thickness and the back thickness, as determined in Sections 8 and 9.

Rows

11. The number of rows of tufts per inch shall be determined by counting a space of not less than 10 in. in at least three different places. No two count determinations shall include the same rows. The row count of the fabric shall be the average of the number of rows per inch in these three tests.

Pitch

12. The number of pile ends per inch of width shall be determined by counting the tufts in a space of not less than 10 in. in at least three different places staggered across the piece. The pitch of the fabric shall be the average of the number of pile ends per inch found in these three tests.

Shot

13. The number of shots in a single repeat of the weaving cycle, or the number of travels of filling yarn per row of tufts, shall be noted. This number shall be the shot of the fabric. In Axminster weaves or fabrics woven on a needle loom, the double thread or filling left by one movement of the needle shall be considered as one shot.

Dissection

14. Samples, in standard condition and which have not been oven-dried, shall be completely picked apart dividing the yarn according to its

utility in the carpet, that is pile, warp, stuffer and filling. The debris from the dissection shall be included in the pile yarn weight.

Weights

15. (*a*) The yarns sorted according to their construction purpose shall be weighed under standard conditions.

(*b*) *Pile Yarn.*—The average of the weights of the samples of pile yarn shall be the conditioned weight of pile yarn.

(*c*) *Clean Pile Yarn.*—The average of the weights of the samples of pile yarn, after extraction to remove fats and after desizing to remove sizing materials, shall be the conditioned weight of clean pile yarn.

(*d*) *Warp Yarn.*—The average of the weights of the samples of warp yarn shall be the conditioned weight of warp yarn.

(*e*) *Stuffer Yarn.*—The average of the weights of the samples of stuffer yarn shall be the conditioned weight of stuffer yarn.

(*f*) *Filling Yarn.*—The average of the weights of the samples of filling yarn shall be the conditioned weight of filling yarn.

(*g*) *Weights per Square Yard.*—Each of the conditioned weights of pile, clean pile, warp, stuffer and filling yarn, determined in accordance with Paragraphs (*b*) to (*f*), shall be corrected to the weight per square yard by multiplying by the proper constant and shall be reported as the weight of pile yarn, clean pile yarn, warp yarn, stuffer yarn and filling yarn per square yard, respectively.

(*h*) *Clean Backing Yarns.*—When required, the average of the weights of the samples of warp yarn, stuffer yarn and filling yarn after extractions to remove fats and after desizing to remove size, shall be the conditioned weight of clean warp yarn, clean stuffer yarn and clean filling yarn, respectively.

NOTE.—Methods for desizing and fat removal will be developed and added later.

FASTNESS OF COLOR TO LIGHT

Standard

16. The standard for light fastness shall be a carpet having a wool content of approximately 27 oz. per sq. yd., a pile height of approximately 0.340 in., and made with yarn spun from white carpet wool, which has been stock dyed by the following procedure: The dye solution shall contain 2 per cent of Indigotine, conc. C. I. 1180 (DuPont), 10 per cent of calcined Glauber's salt and 5 per cent of sulfuric acid, based on the weight of the wool. For 1 part of wool by weight, 30 parts of the solution by weight shall be used. The wool shall be dyed in this solution at 90 C. for 45 min.

NOTE.—The fading characteristics of this standard are on record in the National Bureau of Standards in the form of spectrophotometric curves to assure accurate duplication of the standard when necessary. The standard may be obtained at cost from Alexander Smith and Sons Carpet Co., Yonkers, N. Y., by ordering sample ER-312 No. 1687.

Test Specimens

17. Test specimens for the determination of fastness to light shall be approximately 2½ by 4 in. and so cut that the 4-in. dimension shall be parallel to the direction of the chain or warp.

Apparatus

18. The apparatus for exposing the test specimens shall be a Fade-Ometer or similar machine by which fading is produced comparable to that by sunlight. The frame for holding the test specimens shall be so constructed as to permit the mounting of the specimen in such a manner that it cannot bend away from the front of the frame at any point, that the pile touches the front of the frame lightly, that the lower part of the specimen is exposed, and that the exposed area, approximately 1½ by 2 in., is completely surrounded by an unexposed area.

Procedure

19. Two test specimens prepared in accordance with Section 17 and two standards shall be mounted in the frame in such a manner that if there is a noticeable lay to the pile, one directional component of the lay of the pile shall point toward the bottom of the specimen. The four specimens shall then be placed in the Fade-Ometer at the same time. When the standards show a slight fading (about 20 hr.), one standard and one test specimen shall be removed and the number of hours of exposure noted. The exposure of the remaining standard and test specimen shall be continued until they have been exposed for twice the length of time required for the first fading.

Results

20. Each test specimen shall be compared with the standard against which it has been run. The fastness of the color to light shall be considered satisfactory if, after both the first and second periods of exposure, the change in color in the test specimen is less than that in the standard.

TENTATIVE DEFINITIONS AND TERMS RELATING TO TEXTILE MATERIALS[1]

A.S.T.M. Designation: D 123 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1921; Adopted in Amended Form, 1927; Revised 1930; Reissued as Tentative, 1933; Revised, 1934, 1935, 1936, 1937, 1938.

Absolute Humidity.—See Humidity, Absolute.

Acetate Rayon.—Under Rayon, see Acetate Rayon.

Asbestos, Chrysotile.—An inorganic fiber, occurring naturally as a mineral characterized by 12 to 14 per cent water of crystallization, and having magnesium silicate as its principal component.

Asbestos Roving.—See Roving, Asbestos.

Asbestos Yarn.—See Yarn, Asbestos.

Atmosphere, Standard (Textiles).—Air maintained at a relative humidity of 65 per cent at 70 F. (21 C.).

Note.—Permissible tolerances are given in various standards.

Backing Yarn.—See Yarn, Backing.

Breaking Load.—See Load, Breaking.

Cable Twist.—See Twist, Cable.

Camel Hair.—The hair of the camel, either *Camelus dromedarius* or *Camelus bactrianus.*

Change, Process.—A generic term for alterations in weight or dimension undergone by a fabric, fiber, or yarn subjected to a particular process. Changes including the following:

(*a*) *Gain.*—An increase in weight.

(*b*) *Loss.*—A decrease in weight.

(*c*) *Shrinkage.*—A decrease in dimension or weight.

(*d*) *Stretch.*—An increase in dimension.

Chrysotile Asbestos.—See Asbestos, Chrysotile.

Commercial Moisture Regain.—See Moisture Regain, Commercial.

Commercial Weight.—See Weight, Commercial.

Cotton.—Unicellular seed hairs of the genus *Gossypium.*

Count (Yarns per Inch).—The number of warp or filling yarns per inch.

Note.—The count of a woven textile fabric is expressed in terms of the number of warp and filling yarns per inch.

Crimp (Yarn in Fabric).—The difference in distance between two points on a yarn as it lies in a fabric and the same two points when the yarn has been removed from the fabric and straightened, expressed as a percentage of the distance between the two points as the yarn lies in the fabric.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

Cuprammonium Rayon.—Under Rayon, see Cuprammonium Rayon.

Cut.—A unit of yarn number. The number of 100-yd. lengths per pound avoirdupois of asbestos yarn, or the number of 300-yd. lengths per pound avoirdupois of woolen yarn. (See Yarn Numbering Systems.)

Denier.—A unit of yarn number. The number of unit weights of 0.05 g. per 450-meter length. (See Yarn Numbering Systems.)

Note 1.—Denier is equal numerically to the number of grams per 9,000 meters.

Note 2.—The "New International Denier" is equal numerically to the number of grams per 10,000 meters.

Dew Point.—The temperature at which condensation of moisture would occur if the existing atmosphere were cooled without change in water vapor pressure.

End.—An individual warp yarn.

Fiber.—A slender, elongated filament, such as rayon, silk, or wool; or a single elongated cell like cotton or kapok; or a slender strand composed of aggregations of elongated cells like flax, jute, and sisal.

Fibers, Hard or Leaf.—Comparatively stiff elongated strands from leaves or leaf stems of abaca, henequen, phormium, sisal, and other plants.

Fibers, Soft or Bast.—Flexible elongated strands from the inner bark of flax, hemp, jute, ramie, and other plants.

Fibers, Textile.—Fibers or filaments that can be spun into a yarn or made into a fabric by interlacing in a variety of methods, including weaving, knitting, braiding, felting, and twisting.

Note.—The essential requisites for fibers to be spun into yarn include a length at least 5 mm. and more than 100 times the diameter, also pliability, cohesiveness, and sufficient strength. Other properties, more or less desirable, include elasticity fineness, uniformity, durability, and luster.

Filament.—A fine fiber.

Flax.—A fiber from the inner bark of the fiber flax plant *Linum usitatissimum.*

Note.—Yarn and fabric made from flax are known as linen yarns and linen fabrics.

Float: 1. (Woven Fabric).—The portion of a warp of filling yarn that extends unbound over two or more filling or warp yarns.

2. (Defect).—The portion of a warp or filling yarn that extends unbound over yarn with which it should be interlaced.

Gage: (Full Fashioned Hosiery).—A measure of fineness expressing the number of needles per 1.5 in.

Note.—In connection with textile materials "gage" is occasionally used in place of the preferred term "thickness."

Gain.—Under Change, see Gain.

Grease Wool.—See Wool, Grease.

Hank.—A unit of yarn length, the length varying with different fibers. (See Yarn Numbering Systems.)

Hawser Twist.—See Twist, Hawser.

Hemp.—A fiber from the inner bark of the hemp plant *Cannabis sativa.*

Humidity, Absolute.—Actual density of water vapor in the atmosphere, usually expressed in grains per cubic foot.

Humidity, Relative.—Ratio of actual density (or pressure) of existing water vapor, to maximum possible density (or pressure) of water vapor in the atmosphere at the same temperature, expressed as a percentage.

Jute.—A fiber from the inner bark of the round pod jute *Corchorus capsularis*, or the long pod jute *Corchorus olitorius.*

Lea.—1. A unit of yarn length. A 300-yd. hank of linen yarn.

2. A skein used for strength tests. The skein contains 80 turns each 1.5 yd. in length.

Linen.—Yarn, thread, or fabric made from flax fibers.

Load, Breaking.—For a specimen of any material, the maximum load developed in a tension test carried to rupture. The breaking load is read directly from the testing instrument.

Loss.—Under Change, see Loss.

Mohair.—The hair of the Angora goat.

Moisture (Moisture Content, Percentage of Moisture).—The moisture present in a textile material, as determined by definite prescribed methods, expressed as a percentage of the original weight.

Moisture Regain.—The moisture present in a textile material, as determined by definite prescribed methods, expressed as a percentage of the oven-dry weight.

Moisture Regain, Commercial.—An arbitrary figure formally adopted as the regain to be used in calculating the commercial or legal weight of shipments or deliveries of any specific textile material.

Moisture Regain, Standard: 1. (Individual Samples).—The moisture regain of a sample of textile material when brought from a lower moisture regain into equilibrium with the standard atmosphere. The lower moisture regain may be that reached at equilibrium in any atmosphere having a relative humidity between 5 and 50 per cent.

2. (Type of Fiber).—The range of moisture regain values, through which the standard moisture regain of different individual samples of the same fiber type will vary, depending upon their previous history and physical condition.

Nitrocellulose Rayon.—Under Rayon, see Nitro Rayon.

Number of Yarn.—See Yarn, Number.

Oven-Dry Weight.—See Weight, Oven-Dry.

Pick.—An individual filling yarn.

Pile.—The raised loops or tufts (cut loops) that form all or part of the surface of a pile fabric.

Pile Yarn.—See Yarn, Pile.

Pitch (Pile Floor Covering).—The number of pile ends per inch of width.

Porter.—See Yarn, Porter.

Pressure, Water Vapor.—See Water Vapor Pressure.

Process Change.—See Change, Process.

Pulled Wool.—See Wool, Pulled.

Rayon.—A generic term for filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice and solidifying it in the form of a filament.

NOTE.—Rayon is marketed in two forms: (*1*) continuous filament yarn, and (*2*) staple fibers of spinnable length. Four distinct manufacturing processes are used to make the following varieties:

(*a*) *Acetate Rayon or Cellulose Acetate Rayon.*—Filaments composed of an acetic ester of cellulose which has been coagulated or solidified from its solution.

(*b*) *Cuprammonium Rayon.*—Filaments composed of regenerated cellulose which has been coagulated or solidified from a solution of cellulose in ammoniacal copper oxide.

(*c*) *Nitro Rayon or Nitrocellulose Rayon* (Chardonnet).—Filaments composed of regenerated cellulose (denitrated cellulose) which has been coagulated or solidified from a solution of nitrated cellulose.

(*d*) *Viscose Rayon.*—Filaments composed of regenerated cellulose which has been coagulated or solidified from a solution of cellulose xanthate.

Rayon Staple.—Rayon fibers of spinnable length manufactured directly or by cutting continuous filaments.

Rayon Yarn, Spun.—See Yarn, Spun Rayon.

Regain, Moisture.—See Moisture Regain.

Relative Humidity.—See Humidity, Relative.

Roving.—An assemblage of carded or combed fibers drawn into a single strand, essentially without twist. An intermediate stage between sliver and yarn.

Roving, Asbestos.—An assemblage of chrysotile asbestos and other fibers rubbed into a single strand without twist.

Roving, Reinforced Asbestos.—Asbestos roving containing a core of other fibers.

Sewing Thread.—See Thread, Sewing.

Shot (Pile Floor Covering).—The number of filling yarns per row of tufts.

Shotting Yarn.—See Yarn, Shotting.

Shrinkage.—Under Change, see Shrinkage.

Silk.—The filaments obtained from the cocoons of various types of silkworms.

Single Yarn.—See Yarn, Single.

Size, Yarn.—See Yarn Number.

Smash.—A place in the fabric where a number of warp or filling yarns have been broken.

Spun Rayon.—See Yarn, Spun Rayon.

Standard Atmosphere.—See Atmosphere, Standard.

Standard Moisture Regain.—See Moisture Regain, Standard.

Staple Rayon.—See Rayon Staple.

Strength (Fiber Strength, Skein Strength, Cord Strength, Fabric Strength, etc.).—The breaking load (see Load, Breaking) of the material when tested under specified atmospheric conditions, size of specimen, and method of test.

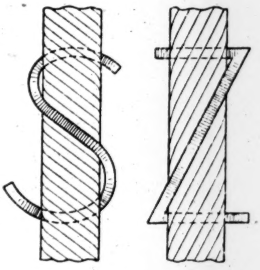
Strength, Tensile.—The strength of a material measured in force per unit cross-sectional area of the original specimen or its equivalent (for example, grams-per-denier of the yarn before test).

Stretch.—Under Change, see Stretch

Textile Fibers.—See Fibers, Textile.

Thread, Sewing.—A variety of yarn, normally plied, characterized by a combination of twisting and finishing with solid or semisolid, wax-like materials to secure a smooth, compact strand which is quite flexible but presents no loose fibers.

Twist, Direction of.—A yarn or cord has **S** twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and **Z** twist if the spirals conform in slope to the central portion of the letter "Z."



"S" Twist "Z" Twist

Twist, Cable.—A twine, cord, or rope construction in which each successive twist is in the opposite direction to the preceding twist, an S/Z/S or Z/S/Z construction.

Twist, Hawser.—A twine, cord, or rope construction in which the single and first ply twist are in the same direction, and the second-ply twist is in the opposite direction, an S/S/Z or Z/Z/S construction.

Typp.—A unit of yarn number. The number of thousands of yards per pound avoirdupois.

Viscose Rayon.—Under Rayon, see viscose rayon.

Water Vapor Pressure.—The component of atmospheric pressure caused by presence of water vapor. Water vapor pressure is expressed in inches or millimeters of mercury.

Weight, Commercial.—The oven-dry weight of a textile material plus the weight corresponding to its commercial moisture regain.

Weight, Oven-Dry.—The weight of a textile material determined after drying by definite prescribed methods.

Wire-Twisted Yarn.—See Yarn, Metallic-Asbestos.

Wool, Grease.—Wool as it comes from the living sheep, not washed or scoured.

Wool, Pulled.—Wool taken from the skin of slaughtered sheep's pelt by slipping, sweating or the use of depilatory.

Wool, Top.—A continuous untwisted band of wool fibers from which the shorter fibers or noils have been removed by combing.

Woolen Yarn.—See Yarn, Woolen.

Worsted Yarn.—See Yarn, Worsted.

Yarn.—See Yarn, Single.

Yarn, Asbestos.—Yarn consisting of (*1*) asbestos fiber, (*2*) asbestos and other fibers, (*3*) asbestos and other fibers and wire, or (*4*) asbestos and other fibers with an insert of cotton or other yarn reinforcement.

Yarn, Plain Asbestos.—Yarn consisting of (*1*) asbestos fiber, or (*2*) asbestos and other fibers.

Yarn, Metallic Asbestos.—Yarn consisting of plain asbestos yarn twisted with brass, copper or other fine wire. It is also termed "wire-twisted yarn."

Yarn, Reinforced Asbestos.—Plain asbestos yarn with an insert of yarn made of other fibers.

Yarn, Backing (Pile Fabric).—The base yarn that holds the pile in place, formed by the stuffer yarn and the warp and filling of the fabric.

Yarn Number.—A conventional relative measure of fineness. Two systems are used:

(*1*) The number (units) of standard lengths per standard weight, as in asbestos, cotton, linen, and wool.

(*2*) The number (units) of standard weights per standard length, as in jute, rayon, and silk.

NOTE 1.—The number of cotton, jute, linen, woolen, worsted, spun rayon, and spun silk yarn is determined under standard atmospheric conditions.

The number of silk and continuous filament viscose and cuprammonium rayon is measured with commercial regain of 11 per cent.

The number of acetate rayon yarn is measured with commercial regain of 6.5 per cent.

NOTE 2.—Yarn number is sometimes inaccurately termed "yarn count" or "yarn size."

Yarn Numbering Systems:

NOTE.—The fineness of single yarns is defined below in the units currently used for the common fibers. The definitions also apply to the equivalent single number of plied yarns.

Asbestos (*Cut*).—The number of 100-yd. lengths per pound avoirdupois.

Cotton (*Hank*).—The number of 840-yd. hanks per pound avoirdupois.
(*Typp*).—The number of thousands of yards per pound avoirdupois.

Jute (*Spyndle*).—The weight in pounds avoirdupois of a spyndle of 14,400 yd. of yarn expressed as "pounds per spyndle."

Linen (*Hank or Lea*).—The number of 300-yd. hanks, or leas, contained in one pound avoirdupois.

Rayon, Continuous Filament (*Denier*).—The number of unit weights of 0.05 g. per 450-meter length.

Rayon, Staple (*Denier*).—The number of unit weights of 0.05 g. per 450-meter length.

Rayon, Spun (*Typp*).—The number of thousands of yards per pound avoirdupois.

Silk, Raw or Boiled-Off (*Denier*).—The number of unit weights of 0.05 g. per 450-meter length.

Silk, Spun (*Hank*).—The number of 840-yd. hanks per pound avoirdupois.

Woolen (*Cut*).—The number of 300-yd. "cuts" or hanks per pound avoirdupois.
(*Run*).—The number of 1600-yd. hanks per pound avoirdupois.

Woolen or Worsted (*Typp*).—The number of thousands of yards per pound avoirdupois.

Worsted (*Hank*).—The number of 560-yd. hanks per pound avoirdupois.

Yarn, Pile.—The yarn forming the loops or tufts (cut loops) of a pile fabric.

Yarn, Porter.—The two-ply warp yarn used in weaving gunny sacking.

Yarn, Single.—An assemblage of fibers or filaments, either natural or manufactured, twisted or laid together to form a strand for use in weaving, knitting or forming in any manner into textile materials.

Yarn, Shotting.—A single filling yarn used in weaving gunny sacking.

Yarn Size.—See Yarn Number.

Yarn, Spun Rayon.—Yarn spun from rayon staple.

Yarn, Woolen.—Yarn spun from wool fibers which have been carded but not combed or gilled.

Yarn, Worsted.—Yarn spun from wool fibers which have been scoured, carded, and either gilled or combed, or both.

TENTATIVE SPECIFICATIONS
FOR
SODA ASH[1]

A.S.T.M. Designation: D 458 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. These specifications cover material suitable for various washing, cleaning and scouring processes, with or without soap as conditions demand, and where a moderately strong alkaline material is desired.

Soda Ash

2. Soda ash shall be a high-grade anhydrous sodium carbonate in powdered form and shall be of the type specified by the purchaser.

NOTE.—These specifications cover the 58 per cent (Na_2O) grade of soda ash.

Chemical Composition

3. Soda ash, after drying for 1 hr. at 155 C., shall conform to the following requirements as to chemical composition:

Total alkalinity as Na_2CO_3, min., per cent	99.16
Sodium bicarbonate ($NaHCO_3$), max., per cent	0.5
Matter insoluble in water, max., per cent	0.25

Loss on Heating

4. (*a*) At the place of manufacture, the loss in weight on heating 2 g. of the material at 150 to 155 C. for 1 hr. shall not exceed 1 per cent.

(*b*) When the sample is taken at other than the place of manufacture, it shall be recognized that the soda ash is hygroscopic. Hence from the percentage loss in weight on heating, there shall be deducted the percentage gain in net weight of the package as sampled over the net shipping weight, to arrive at the percentage loss in weight on heating at the place of manufacture.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

Types

5. Types of soda ash shall be designated as follows on the basis of the density as received:

	Apparent Volume of 30 g., ml.		Apparent Density, lb. per cu. ft.	
	Min.	Max.	Min.	Max.
Light	50	65	29	37
Extra-light	75	95	20	25

Methods of Sampling and Analysis

6. The material shall be sampled and analyzed in accordance with the Tentative Methods of Chemical Analysis of Special Detergents (A.S.T.M. Designation: D 501) of the American Society for Testing Materials.[1]

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[1] See p. 1258.

TENTATIVE SPECIFICATIONS
FOR
CHIP SOAP[1]

A.S.T.M. Designation: D 496 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover chip soap suitable for high-grade laundry work with soft water, when the presence of alkaline salts is objectionable.

General Requirements

2. Chip soap shall be a soap in chip form made from soda and fats, without rosin, as free as possible from water and all substances other than true soap, of a light uniform color, and free from disagreeable odor.

Chemical Composition

3. Chip soap shall conform to the following requirements as to chemical composition. The percentage of matter volatile at 105 C. shall be calculated on the basis of the soap as received, but all other constituents shall be calculated on the basis of material containing 10 per cent of matter volatile at 105 C.

Moisture and matter volatile at 105 C., max., per cent	10.0[a]
Sum of free alkali, total matter insoluble in alcohol, and sodium chloride, max., per cent	4.0
Free alkali, calculated as NaOH, max., per cent	0.20
Matter insoluble in water, max., per cent	1.0
Titer of the mixed fatty acids prepared from the soap, min	39 C.
Anhydrous soap, min., per cent	85.0

[a] Deliveries which yield more than 10 per cent volatile matter will be rejected without further test.

Basis of Purchase

4. Chip soap is subject to a possible gain or loss of weight, depending on atmospheric or storage conditions, or both, or on packaging, as a result of fluctuation in the moisture content. Changes in the moisture content result in a corresponding change in the percentage of total solids or anhydrous soap, or both.

(*a*) The material shall be purchased by net weight provided the matter volatile at 105 C. is neither above nor below 8 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

(*b*) Deliveries containing more than 10 per cent of matter volatile at 105 C. shall be rejected without further test.

(*c*) On deliveries containing less than 10 per cent of matter volatile at 105 C. settlement shall be made on the basis of a product containing 8 per cent of moisture, that is, 0.92 lb. of non-volatile matter shall be considered 1 lb. of soap.

(*d*) When the material conforms to these specifications on a calculated 10.0 per cent moisture and volatile matter basis the net weight of the material to be paid for shall be calculated as follows:

$$\begin{array}{c}\text{Net weight of material to be paid for on 8 per}\\ \text{cent moisture and volatile matter basis}\end{array} = \frac{\begin{array}{c}\text{Net weight as received } \times (100 -\\ \text{percentage of loss at 105 C.)}\end{array}}{92}$$

(*e*) In the event that the calculation under Paragraph (*d*) results in a figure greater than 100 per cent, due to low moisture content at the time of cutting, weighing and packing, the seller waives the right to invoice the purchaser for any amount in excess of 100 per cent.

Methods of Sampling and Analysis

5. The material shall be sampled and analysed in accordance with the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460) of the American Society for Testing Materials.[1] The purchaser reserves the right to use any additional available information to ascertain whether the material conforms to these specifications.

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[1] See p. 1212.

TENTATIVE SPECIFICATIONS
FOR
ORDINARY LAUNDRY BAR SOAP[1]

A.S.T.M. Designation: D 497 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover ordinary laundry bar soap suitable for use with moderately hard water for general cleaning and laundry purposes.

General Requirements

2. (*a*) Ordinary laundry bar soap shall be a well-made, uniformly mixed laundry bar soap, made from soda and fats, with no excessive proportion of rosin and a moderate amount of matter insoluble in alcohol.

(*b*) *Odor.*—The odor shall not be objectionable in the soap as received or in a hot solution of the soap in water. The material shall not leave objectionable odor on dishes or other objects after washing with a water solution of the soap and rinsing thoroughly with hot water. If desired, the odor of the material under the above conditions shall conform to the odor of a sample mutually agreed upon by the purchaser and the seller. The sample mutually agreed upon shall be kept in an air-tight, closed container for comparison with samples from deliveries.

Chemical Composition

3. Ordinary laundry bar soap shall conform to the following requirements as to chemical composition. The percentage of matter volatile at 105 C. shall be calculated on the basis of the soap as received, but all other constituents shall be calculated on the basis of material containing 36 per cent of matter volatile at 105 C.

	MAXIMUM	MINIMUM
Moisture and matter volatile at 105 C., per cent	36.0[a]	...
Sum of free alkali or free acid, total matter insoluble in alcohol, and sodium chloride, per cent	10	2.0
Free alkali, calculated as NaOH, per cent	0.5	...
Free acid, calculated as oleic acid, per cent	0.5	...
Matter insoluble in water, per cent	1.0	...
Rosin, per cent	25.0	...
Sodium chloride (NaCl), per cent	1.0	...
Anhydrous soap, per cent	...	52.0

[a] Deliveries which yield more than 36 per cent volatile matter will be rejected without further test.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

Basis of Purchase

4. Ordinary laundry bar soap is subject to a possible gain or loss of weight, depending on atmospheric or storage conditions, or both, or on packaging, as a result of fluctuation in the moisture content. Changes in the moisture content result in a corresponding change in the percentage of total solids or anhydrous soap, or both.

(*a*) The material shall be purchased by net weight provided the matter volatile at 105 C. is neither above nor below 34 per cent.

(*b*) Deliveries containing more than 36 per cent of matter volatile at 105 C. shall be rejected without further test.

(*c*) On deliveries containing less than 36 per cent of matter volatile at 105 C. settlement shall be made on the basis of a product containing 34 per cent moisture, that is, 0.66 lb. of non-volatile matter shall be considered 1 lb. of soap.

(*d*) When the material conforms to these specifications on a calculated 36 per cent moisture and volatile matter basis the net weight of the material to be paid for shall be calculated as follows:

$$\begin{array}{c}\text{Net weight of material to be paid for on 34 per} \\ \text{cent moisture and volatile matter basis}\end{array} = \frac{\begin{array}{c}\text{Net weight as received} \times (100 - \\ \text{percentage of loss at 105 C.})\end{array}}{66}$$

(*e*) In the event that the calculation under Paragraph (*d*) results in a figure greater than 100 per cent, due to low moisture content at the time of cutting, weighing and packing, the seller waives the right to invoice the purchaser for any amount in excess of 100 per cent.

Methods of Sampling and Analysis

5. The material shall be sampled and analysed in accordance with the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460) of the American Society for Testing Materials.[1] The purchaser reserves the right to use any additional available information to ascertain whether the material conforms to these specifications.

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[1] See p. 1212.

TENTATIVE SPECIFICATIONS
FOR
POWDERED LAUNDRY SOAP[1]

A.S.T.M. Designation: D 498 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover powdered soap suitable for high-grade laundry work with soft water, when the presence of alkaline salts is objectionable.

General Requirements

2. Powdered soap for laundry use shall be a soap in powdered form made from soda and fats, without rosin, as free as possible from water and all substances other than true soap, of a light uniform color, and free from disagreeable odor.

Chemical Composition

3. Powdered laundry soap shall conform to the following requirements as to chemical composition. The percentage of matter volatile at 105 C. shall be calculated on the basis of the soap as received, but all other constituents shall be calculated on the basis of material containing 6 per cent of matter volatile at 105 C.

Moisture and matter volatile at 105 C., max., per cent	6.0[a]
Sum of free alkali, total matter insoluble in alcohol, and sodium chloride, max., per cent	4.0
Free alkali, calculated as NaOH, max., per cent	0.20
Matter insoluble in water, max., per cent	1.0
Titer of the mixed fatty acids prepared from the soap, min	39 C.
Residue retained on a 1680-micron (No. 12) sieve, max., per cent	1.5
Anhydrous soap, min., per cent	89.0

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[a] Deliveries which yield more than 6 per cent volatile matter will be rejected without further test.

Basis of Purchase

4. Powdered laundry soap is subject to a possible gain or loss of weight, depending on atmospheric or storage conditions, or both, or on packaging, as a result of fluctuation in the moisture content. Changes in the moisture content result in a corresponding change in the percentage of total solids or anhydrous soap, or both.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

(*a*) The material shall be purchased by net weight provided the matter volatile at 105 C. is neither above nor below 4 per cent.

(*b*) Deliveries containing more than 6 per cent of matter volatile at 105 C. shall be rejected without further test.

(*c*) On deliveries containing less than 6 per cent of matter volatile at 105 C. settlement shall be made on the basis of a product containing 4 per cent of moisture, that is, 0.96 lb. of non-volatile matter shall be considered 1 lb. of soap.

(*d*) When the material conforms to these specifications on a calculated 6 per cent moisture and volatile matter basis the net weight of the material to be paid for shall be calculated as follows:

$$\begin{array}{c}\text{Net weight of material to be paid for on 4 per}\\ \text{cent moisture and volatile matter basis}\end{array} = \frac{\begin{array}{c}\text{Net weight as received} \times (100 -\\ \text{percentage of loss at 105 C.)}\end{array}}{96}$$

(*e*) In the event that the calculation under Paragraph (*d*) results in a figure greater than 100 per cent, due to low moisture content at the time of cutting, weighing and packing, the seller waives the right to invoice the purchaser for any amount in excess of 100 per cent.

Methods of Sampling and Analysis

5. (*a*) The material shall be sampled and analysed in accordance with the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460) of the American Society for Testing Materials.[1] The purchaser reserves the right to use any additional available information to ascertain whether the material conforms to these specifications.

(*b*) The sieve analysis shall be made in accordance with the Tentative Methods of Test for Particle Size of Soaps and Other Detergents (A.S.T.M. Designation: D 502 – 38 T) of the American Society for Testing Materials.[2]

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[1] See p. 1212.

[2] See p. 1236.

TENTATIVE SPECIFICATIONS

FOR

MILLED TOILET SOAP[1]

A.S.T.M. Designation: D 455 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Scope

1. These specifications cover milled toilet soap.

General Requirements

2. Milled toilet soap shall be a high-grade, milled cake soap, either colored or uncolored, mildly perfumed unless otherwise specified, as free as possible from water, thoroughly saponified, and well compressed in firm, smooth cakes of a size and shape specified in the contract. It should lather freely when used with cold, soft water.

Chemical Composition

3. Milled toilet soap shall conform to the following requirements as to chemical composition. The percentage of matter volatile at 105 C. shall be calculated on the basis of the soap as received, but all other constituents shall be calculated on the basis of material containing 15 per cent of matter volatile at 105 C.

Moisture and matter volatile at 105 C., max., per cent	15[a]
Sum of free alkali, total matter insoluble in alcohol and sodium chloride, max., per cent	1.7
Free alkali, calculated as NaOH, max., per cent	0.1
Matter insoluble in water, max., per cent	0.4
Unsaponified saponifiable matter (free fat), max., per cent	0.3
Rosin, sugar and foreign matter	none
Anhydrous soap, min., per cent	83.0

[a] Deliveries which yield more than 15 per cent volatile matter will be rejected without further test.

Basis of Purchase

4. Milled toilet soap is subject to a possible gain or loss of weight, depending on atmospheric or storage conditions, or both, or on packaging, as a result of fluctuation in the moisture content. Changes in the moisture

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

content result in a corresponding change in the percentage of total solids or anhydrous soap, or both.

(*a*) The material shall be purchased by net weight provided the matter volatile at 105 C. is neither above nor below 12 per cent.

(*b*) Deliveries containing more than 15 per cent of matter volatile at 105 C. shall be rejected without further test.

(*c*) On deliveries containing less than 15 per cent of matter volatile at 105 C. settlement shall be made on the basis of a product containing 12 per cent moisture, that is, 0.88 lb. of nonvolatile matter shall be considered 1 lb. of soap.

When the material conforms to the specifications on a calculated 15 per cent moisture and volatile matter basis the net weight of the material to be paid for shall be calculated as follows:

$$\text{Net weight of material to be paid for on 12 per cent moisture and volatile matter basis} = \frac{\text{Net weight as received} \times (100 - \text{percentage of loss at 105 C.})}{88}$$

In the event that the above calculation results in a figure greater than 100 per cent due to low moisture content at the time of cutting, weighing and packing, the seller waives the right to invoice the purchaser for any amount in excess of 100 per cent.

Method of Sampling and Analysis

5. The material shall be sampled and analysed in accordance with the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460 – 38 T) of the American Society for Testing Materials.[1] The purchaser reserves the right to use any additional available information to ascertain whether the material conforms to the specifications.

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[1] See p. 1212.

TENTATIVE SPECIFICATIONS
FOR
WHITE FLOATING TOILET SOAP[1]

A.S.T.M. Designation: D 499 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These specifications cover white floating toilet soap.

General Requirements

2. White floating toilet soap shall be a cake soap, of good light color, without objectionable odor, thoroughly saponified, and so prepared as to float on water.

Chemical Composition

3. White floating toilet soap shall conform to the following requirements as to chemical composition. The percentage of matter volatile at 105 C. shall be calculated on the basis of the soap as received, but all other constituents shall be calculated on the basis of material containing 34 per cent of matter volatile at 105 C.

Moisture and matter volatile at 105 C., max., per cent	34.0[a]
Sum of free alkali, total matter insoluble in alcohol, and sodium chloride, max., per cent	2.0
Free alkali, calculated as NaOH, max., per cent	0.10
Matter insoluble in water, max., per cent	0.20
Rosin, sugar, and foreign matter	none
Acid number of the mixed fatty acids prepared from the soap, min.	212
Anhydrous soap, min., per cent	62.0

[a] Deliveries which yield more than 34 per cent volatile matter will be rejected without further test.

Basis of Purchase

4. White floating toilet soap is subject to a possible gain or loss of weight, depending on atmospheric or storage conditions, or both, or on packaging, as a result of fluctuation in the moisture content. Changes in the moisture content result in a corresponding change in the percentage of total solids or anhydrous soap, or both.

(*a*) The material shall be purchased by net weight provided the matter volatile at 105 C. is neither above nor below 30 per cent.

(*b*) Deliveries containing more than 34 per cent of matter volatile at 105 C. shall be rejected without further test.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of th A.S.T.M. Committee D-12 on Soaps and Detergents.

(*c*) On deliveries containing less than 34 per cent of matter volatile at 105 C. settlement shall be made on the basis of a product containing 30 per cent of moisture, that is, 0.70 lb. of non-volatile matter shall be considered 1 lb. of soap.

(*d*) When the material conforms to these specifications on a calculated 34 per cent moisture and volatile matter basis the net weight of the material to be paid for shall be calculated as follows:

$$\text{Net weight of material to be paid for on 30 per cent moisture and volatile matter basis} = \frac{\text{Net weight as received} \times (100 - \text{percentage of loss at 105 C.})}{70}$$

(*e*) In the event that the calculation under Paragraph (*d*) results in a figure greater than 100 per cent, due to low moisture content at the time of cutting, weighing and packing, the seller waives the right to invoice the purchaser for any amount in excess of 100 per cent.

Methods of Sampling and Analysis

5. The material shall be sampled and analysed in accordance with the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460) of the American Society for Testing Materials.[1] The purchaser reserves the right to use any additional available information to ascertain whether the material conforms to these specifications.

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[1] See p. 1212.

TENTATIVE METHODS OF SAMPLING AND CHEMICAL ANALYSIS OF SOAPS AND SOAP PRODUCTS[1]

A.S.T.M. Designation: D 460 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

These methods are identical in substance with the standard methods of the American Oil Chemists Society which were developed by the Committee on Soap Analysis A-1 of that Society, and with those of the American Chemical Society.

Scope

1. (*a*) These methods describe procedures for the sampling and chemical analysis of cake, powdered, flake, liquid, and paste soaps, and soap products.

(*b*) The procedures for sampling and the analytical methods for soaps and soap products appear in the following order:

		SECTION
Sampling	Cake Soaps, Flake and Powdered Soap Products when Packed in Cans or Cartons	3
	Flake and Powdered Soap Products when in Bulk	4
	Liquid Soap	5
	Paste Soap Products	6
Preparation of Samples		7
Moisture	Method A. Matter Volatile at 105 C. (Oven Method)	10
	Method B. Distillation Method	11 to 13
Total Matter Insoluble in Alcohol		14 and 15
Free Alkali or Free Acid		16
Matter Insoluble in Water		17
Total Alkalinity of Matter Insoluble in Alcohol, Alkaline Salts		18
Combined Alkali, Total Anhydrous Soap		19
Chlorides		20 and 21
Unsaponified plus Unsaponifiable Matter		22 to 24
Unsaponifiable Matter		25 to 27
Unsaponified Matter		28
Rosin (Wolff's Method Modified)		29
Preparation of Total Fatty Matter, Fatty and Rosin Acids, and Unsaponified Matter		30 and 31
Titer Test		32 and 33
Acid Number of Fatty Acids		34
Borax		35 and 36
Silica Present as Alkaline Silicates		37
Carbon Dioxide (Carbonates)		38 to 40
Phosphates		41 to 43
Sulfates		44
Glycerol, Sugar and Starch	Glycerol in the Absence of Sugar	45 and 46
	Glycerol in the Presence of Sugars	47
	Starch	48
	Sugar	49 and 50
Combined Sodium and Potassium Oxides		54 to 56

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

SAMPLING

2. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

Cake Soaps, Flake, and Powdered Soap Products when Packed in Cans or Cartons

3. One cake (can or carton) shall be taken at random from not less than 1 per cent of the seller's shipping containers, provided each package contains not less than 50 lb. (22.7 kg.). In the case of smaller containers, a cake (can or carton) shall be taken at random from each lot of containers totaling not more than 5000 lb. (2270 kg.), or fraction thereof. The gross sample shall in all cases consist of not less than three cakes (cans or cartons) taken at random from separate containers. In the case of very large lots where the sample drawn as above will amount to more than 20 lb. (9 kg.), the percentage of packages sampled shall be reduced so that the amount drawn shall not exceed 20 lb. (9 kg.). The individual cakes (cans or cartons) shall be tightly wrapped at once in paraffined paper and sealed by rubbing the edges with a heated iron. The inspector shall accurately weigh each wrapped cake (can or carton), and record its weight and the date of weighing on the wrapper. The wrapped cakes (cans or cartons) shall be placed in an air-tight container, which should be nearly filled, and which shall then be sealed, marked, and sent to the laboratory for test. Samples shall be kept cool until tested.

Flake and Powdered Soap Products when in Bulk

4. A grab sample of not less than 0.5 lb. (227 g.) shall be taken at random from not less than 1 per cent of the seller's shipping containers, provided each package contains not less than 100 lb. (45 kg.). In the case of smaller containers, a grab sample of not less than 0.5 lb. (227 g.) shall be taken at random from each lot of containers totaling not more than 10,000 lb. (4540 kg.), or fraction thereof. The gross sample shall in all cases consist of not less than three grab samples of 0.5 lb. (227 g.) each taken at random from separate containers. In the case of very large lots where the sample drawn as above will amount to more than 20 lb. (9 kg.), the percentage of packages sampled shall be reduced so that the amount drawn shall not exceed 20 lb. (9 kg.). The inspector shall rapidly mix the gross sample, place it in an air-tight container, which shall be filled, sealed, marked, accurately weighed, its weight and the date of weighing recorded on the package, and sent to the laboratory for test. Samples shall be kept cool until tested.

Liquid Soap

5. A sample of not less than 0.5 pt. (236.6 ml.) shall be taken at random from not less than 1 per cent of the seller's shipping containers, provided

each package contains not less than 10 gal. (almost 38 liters). In the case of smaller containers, a sample of not less than 0.5 pt. (236.6 ml.) shall be taken at random from each lot of containers totaling not more than 1000 gal. (37,853 liters), or fraction thereof. The gross sample shall in all cases consist of not less than three samples of 0.5 pt. (236.6 ml.) each taken at random from separate containers. Before drawing the sample from the container selected, the contents of the container shall be thoroughly agitated. The inspector shall thoroughly mix the gross sample, place it in clean, dry cans or bottles, which shall be completely filled and securely stoppered with clean corks or caps, then sealed, marked, and sent to the laboratory for test.

Paste Soap Products

6. (*a*) *When Packed in Cans or Cartons of 5 lb. (2.27 kg.) or Less.*—One can or carton shall be taken at random from not less than 1 per cent of the seller's shipping containers, provided each package contains not less than 50 lb. (22.7 kg.). In the case of smaller containers, a can or carton shall be taken at random from each lot of containers totaling not more than 5000 lb. (2270 kg.), or fraction thereof. The gross sample shall in all cases consist of not less than three cans or cartons taken at random from separate containers. In the case of very large lots where the sample drawn as above will amount to more than 20 lb. (9 kg.), the percentage of packages sampled shall be reduced so that the amount drawn shall not exceed 20 lb. (9 kg.). The samples shall be wrapped, sealed, marked, and sent to the laboratory for test.

(*b*) *When Packed in Bulk.*—A "trier" sample[1] of not less than 0.5 lb. (227 g.) shall be taken at random from not less than 1 per cent of the seller's shipping containers, provided each package contains not less than 50 lb. (22.7 kg.). In the case of smaller containers, a "trier" sample[1] of not less than 0.5 lb. (227 g.) shall be taken at random from each lot of containers totaling not more than 5000 lb. (2270 kg.), or fraction thereof. The gross sample shall in all cases consist of not less than three 0.5-lb. (227-g.) samples, each taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 10 lb. (4.5 kg.), the percentage of packages sampled shall be reduced so that the amount drawn shall not exceed 10 lb. (4.5 kg.). The inspector shall promptly place the gross sample in a clean, dry, air-tight and water-tight container, which shall be filled, sealed, marked, and sent to the laboratory for test.

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[1] A trier sample is obtained by inserting a "trier" into the material. A trier is a half-round steel cylinder $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter, 6 to 36 in. in length, pointed on one end and having a grip handle on the other end. After insertion, the trier is turned two or three times and upon removal a core of the material being sampled will be obtained.

PREPARATION OF SAMPLES

7. (*a*) *Cake Soap.*—In the case of samples of cake soap that can be easily disintegrated and mixed, run the entire sample through a suitable chopper. With samples that cannot be handled in this manner, select a cake of average weight, quarter it by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix the sample and weigh at once all portions for analysis, preserving the remainder in an air-tight container in a cool place.

(*b*) *Powdered and Chip Soaps.*—Rapidly disintegrate and mix the sample of powdered, flake or chip soap; if desired, quarter down to about 1 lb. (453.6 g.). Weigh at once all portions for analysis, preserving the remainder in an air-tight container in a cool place.

(*c*) *Liquid Soap.*—No preparation of the sample of liquid soap, other than a thorough mixing, is necessary unless it is received during very cold weather, when it should be allowed to stand at least 1 hr. after it has warmed up to room temperature (20 to 30 C.) before it is tested, particularly for its lathering qualities.

(*d*) *Paste Soap Products.*—Mix the sample of paste soap products thoroughly by kneading and quarter down to about 1 lb. (453.6 g.). Weigh at once all portions for analysis, preserving the remainder in an air-tight container in a cool place.

METHODS OF CHEMICAL ANALYSIS

Duplicate Tests

8. When a determination shows nonconformity with the specifications a duplicate test shall be made.

MOISTURE

9. The oven method described in Section 10 is generally applicable to all soaps, but certain exceptions to this method must be made if accurate results are desired. These exceptions include the following:

(*a*) For soaps containing appreciable amounts of sodium silicate, the distillation method (Sections 11 to 13) is preferred.

(*b*) Soaps of linseed and other oxidizing oils absorb oxygen and if the oven method is used may gain weight near the end of the test. Therefore, either an inert atmosphere or vacuum oven should be used. The distillation method is also applicable to these types of soap.

Method A. Matter Volatile at 105 C. (Oven Method)

Procedure

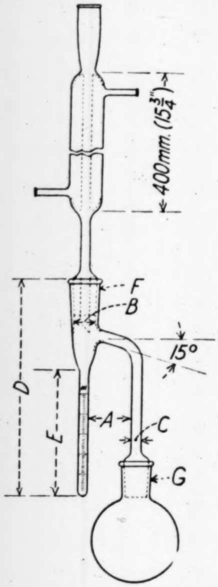
10. Weigh 5 g. ±0.01 g. of the sample in a porcelain or glass dish about 6 to 8 cm. in diameter and about 2 to 4 cm. in depth, and dry to constant weight in an air oven at a temperature of 105 C. ±2 C.

Method B. Distillation Method

Apparatus

11. The apparatus required consists of a glass flask, heated by suitable means and provided with a reflux condenser, discharging into a trap and connected to the flask. The connections between the trap and the condenser and flask shall be interchangeable ground joints. The trap serves to collect and measure the condensed water and to return the solvent to the flask. A suitable assembly of the apparatus is illustrated in Fig. 1.

(*a*) *Flask.*—A 500-ml. flask of either the short-neck, round-bottom type or the Erlenmeyer type shall be used



A = 45 to 55 mm.
B = 22 to 24 mm., inside diameter
C = 9 to 11 mm., inside diameter
D = 235 to 240 mm.
E = 146 to 156 mm.
F and G are interchangeable joints, standard taper 24/40.

FIG. 1.—Assembly of Distillation Apparatus.

(*b*) *Heat Source.*—The source of heat may be either an oil bath (stearic acid, paraffin wax, etc.) or an electric heater provided with a sliding rheostat, or other means of heat control.

(*c*) *Condenser.*—A water-cooled, reflux, glass condenser (Fig. 1), having a jacket approximately 400 mm. (15¾ in.) in length with an inner tube 9.5 to 12.7 mm. (⅜ to ½ in.) in outside diameter shall be used. The end of the condenser to be inserted in the trap shall be ground off at an angle of 30 deg. from the vertical axis of the condenser. When inserted into the trap, the tip of the condenser shall be about 7 mm. (¼ in.) above the surface of the liquid in the trap after the distillation conditions have been established. Figure 1 shows a conventional sealed-in type of condenser, but any other condenser fulfilling the detailed requirements above may be used.

(*d*) *Trap.*—A trap made of well-annealed glass constructed in accordance with Fig. 1 and graduated as shown to contain 5 ml. at 20 C. shall be used. It shall be subdivided into 0.1-ml. divisions, with each 1-ml. line numbered (5 ml. at top). The error in any indicated capacity may not be greater than 0.05 ml.

Special Solutions Required

12. *Xylol.*—Saturate the xylol with water by shaking with a small quantity of water and distill. Use the distillate for the determination.

Procedure

13. For soaps containing from 5 to 25 per cent moisture and volatile matter use 20 g. ± 0.04 g. of the sample. For soaps containing more than 25 per cent moisture and volatile matter use 10 g. ± 0.02 g. of the sample. Carefully transfer the weighed sample to the 500-ml. flask. Add approximately 10 g. of anhydrous, fused sodium acetate to prevent violent frothing, and then follow with 100 ml. of xylol which has been saturated with water. Attach the flask to the trap which is connected to the condenser. Prior to starting the determination, fill the receiver with saturated xylol by pouring in through the reflux condenser.

So that the refluxing will be under better control, wrap the flask and tube leading to the receiver with asbestos cloth. Apply heat to the flask by means of a gas burner or an electric heater and distill slowly. The rate at the start should be approximately 100 drops per minute. When the greater part of the water has distilled over, increase the distillation rate to 200 drops per minute until no more water is collected. Purge the reflux condenser during the distillation with 5-ml. portions of xylol to wash down any moisture adhering to the walls of the condenser. The water in the receiver may be made to separate from the xylol by using a spiral copper wire. Move the wire up and down in the condenser occasionally, thus causing the water to settle at the bottom of the receiver. Reflux for at least 2 hr., and shut off the heat at the end of this period. Adjust the temperature of the distillate to 25 C. Read the volume of water and calculate the percentage of moisture in the soap, as follows:

$$\text{Moisture, per cent} = \frac{\text{Volume in milliliters at 25 C.} \times 0.997}{\text{Weight of sample in grams}} \times 100$$

TOTAL MATTER INSOLUBLE IN ALCOHOL, AND FREE ALKALI OR FREE ACID

Matter Insoluble in Alcohol

Special Solutions Required

14. *Ethyl Alcohol (94 per cent).*—Freshly boiled ethyl alcohol, 94 per cent or higher, and neutral to phenolphthalein.

Procedure

15. Digest 2 to 10 g. ± 0.01 g. of the sample with 200 ml. of freshly boiled ethyl alcohol in a covered vessel on a steam bath until the soap is dissolved. Filter through a counterpoised filter paper, neutral to phenolphthalein, or through a weighed Gooch crucible with suction, protecting the solution from carbon dioxide and other acid fumes during the operation by covering with a watch glass. Wash the residue on the paper, or in the crucible, with hot neutral alcohol until free from soap and reserve the filtrate and washings. Dry the filter paper or crucible with the residue at 100 to 105 C. for 3 hr., cool, and weigh the total matter insoluble in alcohol.

NOTE.—The matter insoluble in alcohol will contain most of the alkaline salts, such as carbonates, borates, silicates, phosphates, and sulfates, as well as starch, and may be used for the approximate determination of these constituents. These salts are not entirely insoluble in alcohol, so for accurate determinations separate portions of the soap should be used. For determination of carbonates, see Sections 38 to 40; phosphates, Sections 41 to 43; sulfates, Section 44; silicates, Section 37; borax, Sections 35 and 36; and starch, Section 48.

Free Alkali or Free Acid

Procedure

16. Heat the reserved filtrate (Section 15) to incipient boiling and titrate with standard acid or alkali solution using phenolphthalein as indicator, and calculate to sodium hydroxide (or potassium hydroxide) if alkaline, or to oleic acid, if acid.

MATTER INSOLUBLE IN WATER

Procedure

17. Proceed as in the determination of matter insoluble in alcohol (Section 15). After filtering and thoroughly washing the residue, change the receivers and extract the residue with water at 60 C. and wash the filter thoroughly. (When the matter insoluble is all inorganic, boiling water may be used for the extraction and washing.) Reserve the water solution. Dry the filter and residue at 100 to 105 C. for 3 hr., cool, and weigh the matter insoluble in water. The nature of this matter may be determined by further examination.

TOTAL ALKALINITY OF MATTER INSOLUBLE IN ALCOHOL, ALKALINE SALTS

Procedure

18. Titrate the water solution obtained in the determination of matter insoluble in water (Section 17) with standard acid, using methyl orange as indicator. Calculate the alkalinity to sodium oxide (Na_2O), and, if desired, to any other basis agreed upon by the purchaser and the seller.

COMBINED ALKALI, TOTAL ANHYDROUS SOAP

Procedure

19. (*a*) Dissolve 5 to 10 g. ± 0.01 g. of the sample, depending upon the anhydrous soap content, in 100 ml. of water in a 250-ml. Erlenmeyer

flask. When the solution is complete, add diluted H_2SO_4 in slight excess, insert a small funnel in the neck of the flask, and heat the flask to a temperature not exceeding 60 C. until the fatty acids separate as a clear layer. Transfer to a separatory funnel, draw off the acid layer into a second separatory funnel, and shake the acid aqueous liquid with two 20-ml. portions of ethyl ether. Dissolve the fatty acids in the ether used for washing the aqueous liquid and shake with 10-ml. portions of water until they are no longer acid to methyl orange. Unite the water portions used for washing and shake with 20 ml. of ether. Wash this ether until the wash water is neutral to methyl orange. Reserve the acid water for the determination of chlorides (Sections 20 and 21).

(*b*) Unite the ether solutions (if necessary, filter, washing the paper with ether) in a suitable weighed vessel, add 100 ml. of neutral alcohol free from carbon dioxide, add phenolphthalein, and titrate to exact neutrality with standard 0.5 *N* NaOH solution. Evaporate the alcohol, dry to constant weight as in the determination of matter volatile at 105 C. (Section 10), and calculate the percentage of soda soap. This naturally includes any mineral oil and neutral fat which, if determined separately, must be deducted from the result to obtain the true soap. Calculate the combined sodium oxide (Na_2O) and deduct from the weight of soda soap to give the acid anhydrides. If the original soap was potash soap, proper calculation must be made to reduce to potassium oxide (K_2O), or the titration made directly with standard 0.5 *N* KOH solution. In case the soap shows an excess of free acid, proper corrections must be made in calculating the combined alkali in the original soap. (A blank test should be made on the NaOH or KOH solution for neutral salts and the proper corrections made if necessary.)

(*c*) In the case of soaps containing a large amount of soluble silicates, and soap products containing a high percentage of finely divided material insoluble in water, the foregoing procedure cannot be applied as given. In such cases the filtrate obtained in the determination of total matter insoluble in alcohol (Section 15) may be used after neutralizing any free acid or alkali. Evaporate the alcohol on a steam bath, take up with water, and proceed according to the procedure given in Paragraphs (*a*) and (*b*).

(*d*) In the case of soap products containing a high percentage of matter insoluble in alcohol where approximate results will suffice, such as cleansers, soap powders, scouring compounds, pastes, etc., and where agreed upon by the purchaser and the seller, the alcoholic solution, obtained after filtering off and washing the matter insoluble in alcohol (Section 15), may be evaporated directly in a weighed vessel, dried at 105 C. to constant weight and the result reported as soap.

CHLORIDES

Special Solutions Required

20. (*a*) *Silver Nitrate Solution (0.1 N).*

(*b*) *Potassium Chromate Indicator.*—Dissolve 5 g. of potassium chromate in water and add solution of silver nitrate until a slight red precipitate is produced, filter the solution, and dilute to 100 ml.

Procedure

21. (*a*) Neutralize with chloride-free alkali the acid water obtained in the determination of combined alkali (Section 19). Titrate with standard silver nitrate solution, using potassium chromate as indicator and calculate the result to NaCl or KCl as the character of the soap indicates.

(*b*) In case the total anhydrous soap is not to be determined, it will be more convenient to use the following method: Dissolve 5 g. ± 0.01 g. of the sample in 300 ml. of water, boiling if necessary to effect solution. Add an excess of neutral, chloride-free magnesium nitrate solution (about 25 ml. of a 20 per cent $Mg(NO_3)_2 \cdot 6H_2O$ solution). Without cooling or filtering, titrate with standard silver nitrate solution, using potassium chromate as indicator. One milliliter of the 0.1 *N* $AgNO_3$ solution is equivalent to 0.00585 g. of NaCl.

UNSAPONIFIED PLUS UNSAPONIFIABLE MATTER

Apparatus

22. *Extraction Cylinder.*—The extraction cylinder shall be a 250-ml. graduated glass-stoppered cylinder about 39 mm. (1½ in.) in diameter and 30.5 cm. (13 in.) in length.

Special Solutions Required

23. (*a*) *Ethyl Alcohol (50 per cent).*

(*b*) *Ethyl Alcohol (95 per cent).*

(*c*) *Ethyl Alcohol (10 per cent).*

(*d*) *Sodium Hydroxide Solution (0.1 N).*

(*e*) *Sodium Hydroxide Solution (0.04 N).*

(*f*) *Petroleum Ether.*—The solvent used shall be of the pentane type, containing a minimum amount of *iso*pentane, *iso*hexane and hexane, conforming to the following requirements:

Distillation Test:	
Initial boiling point	not less than 35 C. nor more than 40 C.
Dry flask endpoint	not less than 50 C. nor more than 60 C.
Distilling under 55 C	not less than 95 per cent
Distilling under 40 C	not more than 85 per cent
Specific gravity at 15.5/15.5 C. (60/60 F.)	0.630 to 0.675
Color	water white
Doctor test	sweet
Evaporation residue	not over 0.002 per cent by weight
Copper-strip corrosion test	non-corrosive
Unsaturated compounds	trace only permitted

Procedure

24. (*a*) Weigh 5 g. ± 0.2 g. of the sample and place it in a 250-ml. Erlenmeyer flask or beaker which contains approximately 0.1 g. of bicarbonate of soda, and dissolve in 100 ml. of redistilled 50 per cent ethyl alcohol. Warm and shake to effect solution, keeping the temperature under 60 C., and filter off any undissolved residue on a Gooch crucible with an asbestos pad or in a funnel, using an asbestos pad deposited on a perforated porcelain disk. Wash three times with hot 50 per cent alcohol. Wash with a small amount of petroleum ether to remove any traces of unsaponified and unsaponifiable matter. Transfer the entire alcohol-water-and-ether filtrate to the extraction cylinder and make up to the 160-ml. mark with redistilled, 50 per cent ethyl alcohol. Add 50 ml. of petroleum ether, shake vigorously for 1 min. (Note 1), and allow to settle until both layers are clear. The volume of the upper layer should be about 40 ml. Draw off the petroleum ether layer as closely as possible, by means of a slender glass siphon, into a separatory funnel of 500-ml. capacity.

(*b*) Repeat the extraction at least six times using 50 ml. of petroleum ether each time (Note 2). Wash the combined ether extracts first with a mixture of 15 ml. of 0.1 *N* sodium hydroxide solution and 15 ml. of 95 per cent alcohol, and then three times with 25-ml. portions of 10 per cent alcohol, shaking vigorously each time. Transfer the petroleum ether extract to a beaker and evaporate the petroleum ether on a steam bath by the aid of a current of air.

NOTE 1.—Thorough and vigorous shaking is necessary in order to secure accurate results. The two phases must be brought into the most intimate contact possible; otherwise low and disagreeing results may be obtained.

NOTE 2.—This method will not remove all the unsaponifiable matter in soaps to which lanolin has been added. More extractions are required when substances of this nature are present.

(*c*) Test the residue for solubility by treating with 50 ml. of petroleum ether at room temperature. Filter, and wash free from the insoluble residue, if any; evaporate and dry in the same manner on a steam bath, and finally in an air oven at 100 to 101 C. for 30 min. Weigh, and return to the oven, reweighing at 15-min. intervals until constant weight is reached. Take up the residue in 50 ml. of warm ethyl alcohol, neutralized to phenolphthalein, titrate to the same color as the original neutral alcohol with 0.04 *N* NaOH solution and calculate to oleic acid. Deduct this figure from the gross weight previously found and report as "unsaponified and unsaponifiable matter."

(*d*) Make a blank test on the petroleum ether by evaporating 250 ml. of the ether with about 0.25 g. of stearin or some other hard fat previously brought to constant weight by heating and drying as in the actual determination. The blank must not exceed a few milligrams.

NOTE.—Any blank from the petroleum ether must be deducted from the weight before calculating the unsaponified and unsaponifiable matter.

UNSAPONIFIABLE MATTER

Apparatus

25. *Extraction Cylinder.*—See cylinder described in the determination of unsaponified plus unsaponifiable matter (Section 22).

Special Solutions Required

26. (*a*) See the special solutions required in the determination of unsaponified plus unsaponifiable matter (Section 23).

(*b*) *Potassium Hydroxide Solution* (*50 per cent*).

Procedure

27. Weigh 5 g. ± 0.2 g. of the sample and place in a 200-ml. Erlenmeyer flask. Add 30 ml. of redistilled 95 per cent alcohol and 5 ml. of aqueous KOH (50 per cent), and boil for 1 hr. under a reflux condenser. Transfer to the extraction cylinder and wash to the 40-ml. mark with redistilled 95 per cent ethyl alcohol. Complete the transfer, first with warm and then with cold water, until the total volume is 80 ml., and finally with a small quantity of petroleum ether. Cool the cylinder to room temperature and add 50 ml. of petroleum ether; then proceed with the extraction as outlined in the procedure for unsaponified plus unsaponifiable matter (Section 24; see also **Notes 1 and 2**), except that the alkaline wash may be omitted. Weigh the residue and correct for fatty acids in the usual manner. Report the result as unsaponifiable matter.

UNSAPONIFIED MATTER

28. From the total unsaponified plus unsaponifiable matter determined in Section 24, deduct the unsaponifiable figure obtained in Section 27 and report the difference as "unsaponified matter."

Rosin (*Wolff's Method, Modified*)

Procedure

29. (*a*) *Preparation of Fatty and Rosin Acids.*—Dissolve 5 g. ± 0.01 g. of the sample in 100 to 200 ml. of hot distilled water in a 250-ml. beaker, add a slight excess of dilute sulfuric acid (1:1), heat on a steam bath until the fatty acids collect in a clear layer, cool to room temperature, and transfer to a separatory funnel, washing the beaker free from fatty and rosin acids with small portions of ethyl ether, adding the ether washings to the separatory funnel, designated as No. 1. Add about 50 ml. of ethyl ether to the separatory funnel and whirl to dissolve the fatty and rosin acids. After the solid acids have dissolved in the ether, allow the solution to stand for at least 5 min.

Draw off the aqueous portion into another separatory funnel designated as No. 2, add about 30 ml. of ethyl ether to funnel No. 2, shake vigorously, allow to stand for at least 5 min., and then draw off the aqueous portion into another separatory funnel designated as No. 3. Transfer the ether extract to separatory funnel No. 1. Wash the aqueous liquid three more times, using for each washing about 30 ml. of ethyl ether, shaking vigorously, then discard the aqueous liquid and add the ether washings to funnel No. 1. Now add 50 ml. of distilled water to the combined ether extracts in funnel No. 1, shake vigorously, and allow to stand for 5 min. Draw off the aqueous solution into another separatory funnel. Repeat this operation, combining the water washings until the ether is free from acid, using methyl orange as indicator. Add 50 ml. of ethyl ether to the water washings, shake the separatory funnel vigorously, and allow to stand for at least 5 min. Draw off and discard the aqueous solution and wash the ether layer with small portions of distilled water until free of acid, using methyl orange as indicator. Transfer the total ether extract to a 250-ml. Erlenmeyer flask, evaporate the ether slowly on the side of a steam bath, dry 1 hr. in an oven at 105 C., cool, and dissolve in 20 ml. of absolute alcohol.

(*b*) *First Esterification.*—Add 10 ml. of a solution of one volume of H_2SO_4 (sp. gr. 1.84) in four volumes of absolute ethyl alcohol, bring to a boil on the steam bath, and boil exactly 4 min. under a reflux condenser. Remove from the steam bath, add to the liquid about five times its volume of a NaCl solution (7 to 10 per cent). Transfer to a separatory funnel, washing the Erlenmeyer flask with small portions of ethyl ether, the ether washings being added to the aqueous solution in the separatory funnel. Add about 30 ml. of ethyl ether to the separatory funnel No. 1, shake vigorously, and allow to stand for at least 5 min.

Draw off the aqueous solution into another funnel, No. 2. Add about 30 ml. of ether to funnel No. 2, shake vigorously, allow to stand for at least 5 min., and then draw off the aqueous layer into another separatory funnel, No. 3. Repeat the extraction of the aqueous solution three times more. Then discard the aqueous liquid and add the combined ether solutions to separatory funnel No. 1. Add 50 ml. of NaCl solution (7 to 10 per cent) to the combined ether extracts, shake vigorously and allow to stand for at least 5 min. Draw off the aqueous solution into another separatory funnel. Repeat this operation until the washings are neutral to methyl orange, all salt water washings being combined. Add 50 ml. of ether to the washings in the separatory funnel. Shake the separatory funnel vigorously, allow to stand for at least 5 min., and then draw off and discard the aqueous salt solution. Add 50 ml. of NaCl solution and wash the ether layer until the aqueous salt solution is neutral to methyl orange. Dry the ether extract by the addition of about 3 g. of anhydrous Na_2SO_4 to the separatory funnel, filter into a 250-ml. Erlenmeyer flask and evaporate off the ether slowly on a steam bath to dryness.

(*c*) *Second Esterification.*—Cool, and dissolve the residue in 20 ml. of absolute ethyl alcohol and then proceed as described for the first esterification in Paragraph (*b*).

(*d*) Add 30 ml. of neutral alcohol (94 per cent or higher) and titrate rosin or rosin soap as desired, using phenolphthalein as indicator (1 ml. 0.5 *N* alkali = 0.173 g. of rosin or 0.188 g. of rosin soda soap). If the pure fatty acid soap is desired, subtract the rosin soap from the total anhydrous soap obtained in Section 19.

NOTE.—This method gives somewhat high results with low-rosin soap and approximately correct results with high-rosin soap. In all cases where the rosin content is found to be less than 5 per cent, the actual presence or absence of rosin should be checked qualitatively by the Liebermann-Storch test, which is as follows:

Transfer 1 to 2 ml. of the sample of fatty acids to a test tube, treat with 5 to 10 ml. of reagent grade acetic anhydride, and warm on a steam bath. After cooling, pour 1 to 2 ml. into a white porcelain dish and allow a drop or two of sulfuric acid (sp. gr. 1.53) to run down the side of the vessel. (The sulfuric acid is prepared by diluting 34.7 ml. of H_2SO_4 (sp. gr. 1.84) with 35.7 ml. of distilled water.) If rosin is present, a fugitive violet coloration changing to a brownish tinge is immediately produced at the margin of contact of the reagents. The test should be checked with a sample of fatty acids to which a small amount of rosin has been added.

.PREPARATION OF TOTAL FATTY MATTER
(FATTY AND ROSIN ACIDS, AND UNSAPONIFIED MATTER)

Special Solutions Required

30. *Sulfuric Acid (30 per cent).*—Slowly add 650 g. of H_2SO_4 (sp. gr. 1.84) to 1400 ml. of water.

Procedure

31. (*a*) *Preparation for Titer Test Only.*—Dissolve about 50 g. of the sample in 500 ml. of hot water, add 100 ml. of H_2SO_4 (30 per cent), heat until the fatty matter collects in a clear layer. Siphon off the aqueous acid layer and wash the fatty matter free from H_2SO_4 with hot water. Decant the fatty matter into a dry beaker, filter, using a hot-water funnel, or placing both funnel and receiving beaker in a water-jacketed oven, and dry for 20 min. at 100 C.

(*b*) *Preparation for Other Tests.*—When other determinations are to be made on the total fatty matter, and volatile and readily oxidizable fatty acids are present, the following method should be used: Dissolve about 50 g. of the sample in 300 ml. of hot water, and transfer to a separatory funnel. Add 150 ml. of approximately 2 *N* H_2SO_4 to the solution in the funnel, cool somewhat and add 120 ml. of ether. Shake the solution, draw off the acid layer, and wash the ether layer free from acid with a strong NaCl solution. Draw off the aqueous layer as completely as possible, transfer the ether layer to a flask (it is not necessary to transfer quantitatively), add 20 to 30 g. of anhydrous Na_2SO_4, stopper the flask, shake and allow to stand at a temperature below 25 C. untll the ethereal liquid becomes perfectly clear, showing that all the water had been taken up by the Na_2SO_4. Filter through a dry filter paper into an Erlenmeyer flask, and completely evaporate the ether by passing through the flask a current of dry air and heating the flask to a temperature of about 50 C.

TITER TEST

Apparatus

32. *Thermometer.*—The thermometer shall be graduated at zero in 0.1 deg. from 10 C. to 65 C. and have an auxiliary reservoir at the upper end. The 10 C. mark shall be about 3 to 4 mm. above the bulb and the length of the thermometer shall be about 37 cm. over all. The thermometer shall have been annealed for 75 hr. at 450 C. and the bulb shall be normal 16 in. glass[1] or its equivalent, moderately thin so that the thermometer will be quick acting. The bulb shall be about 3 cm. in length and 6 mm. in diameter. The stem of the thermometer shall be 6 mm. in diameter and made of the best thermometer tubing, with the scale etched on the stem, the graduation being distinct but quite fine. The thermometer shall be certified by the National Bureau of Standards.

Procedure

33. Transfer the fatty acids (Section 31 (*a*)) when cooled somewhat, to a titer tube 25 by 100 mm. placed in a 273 to 275-ml. (16-oz.) saltmouth bottle of clear glass 70 by 150 mm., fitted with a cork that is perforated so as to hold the tube rigidly when in position. Suspend the titer thermometer so that it can be used as a stirrer and stir the fatty acids slowly (with a circular motion in one plane at about 100 r.p.m.) until the mercury remains stationary for 30 sec. Allow the thermometer to hang quietly with the bulb in the center of the tube and report the highest point to which the mercury rises as the titer of the fatty acids. The titer should be made in a room at about 20 C. for all fats having a titer above 30 C. and at 10 C. below the titer for all other fats.

ACID NUMBER OF FATTY ACIDS

Procedure

34. For the preparation of the sample for this determination follow the procedure described in Section 31 (*b*). In a 250-ml. Erlenmeyer flask dissolve 2 g. of the fatty acids, accurately weighed, in 20 to 30 ml. of neutral 95 per cent ethyl alcohol. Titrate with standard alkali, using phenolphthalein as indicator. Calculate the acid number (milligram of KOH per gram of fatty acids).

BORAX

Special Solutions and Materials Required

35. (*a*) *Sodium Hydroxide Solution (0.1 N).*

(*b*) *Silica, Fine Powder.*

(*c*) *Precipitated Calcium Carbonate.*

(*d*) *Glycerol.*

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[1] Jena glass is very satisfactory for this purpose.

Procedure

36. (*a*) Weigh 10 g. ± 0.02 g. of the sample (or 5 g. ± 0.01 g. if more than 5 per cent of borax is present) into a platinum dish and add 2.15 g. of fusion mixture consisting of 200 g. of sodium carbonate, 15 g. of silica in fine powder. To this mixture add 15 ml. of alcohol (94 per cent or higher), mix with the aid of a glass rod, and after washing the rod with a little alcohol, evaporate the mass to dryness on a water bath. Ignite until the combustible material is destroyed, cover the dish with a piece of platinum foil and fuse.

(*b*) Completely disintegrate the fusion by boiling with water and transfer the solution to a 250-ml. round-bottom flask. Acidify the mixture with 20 ml. of diluted HCl (1:1), heat nearly to boiling, and add a moderate excess of dry precipitated calcium carbonate. Connect the flask with a reflux condenser and boil vigorously for 10 min. Filter out the precipitate through a folded filter, washing several times with hot water, but keeping the total volume of the liquid below 100 ml.

(*c*) Return the filtrate to the flask, add a pinch of calcium carbonate and again boil under a reflux condenser. Remove the flame and connect the top of the condenser with a water pump; apply suction until the boiling has nearly ceased. Cool the mixture to room temperature, add 50 ml. of neutral c. p. glycerol, and titrate the solution with 0.1 *N* NaOH free from carbonate, using phenolphthalein as indicator. After the end point is reached, add 10 ml. more of glycerol and again titrate. Repeat this process until the addition of glycerol causes no further action on the end point. The number of milliliters of NaOH required for the titration, multiplied by 0.00955 will give the equivalent of borax ($Na_2B_4O_7 \cdot 10H_2O$) present in the solution.

SILICA PRESENT AS ALKALINE SILICATES

Procedure

37. (*a*) When the material contains no mineral matter that is insoluble in water, ignite a sample of the soap containing not to exceed 0.2 g. of silica in a platinum dish at a low temperature. When charred, extract the soluble salts with water, return the paper and charred residue to the dish and complete the ignition. Unite the residue in the dish and the water extract, carefully acidify with HCl, finally adding the equivalent of from 5 to 10 ml. of strong HCl in excess. The dish or casserole containing the solution should be covered with a watch glass while adding acid so as to avoid loss by spray.

(*b*) When the material contains mineral matter insoluble in water, or a determination of highest accuracy is not necessary, take a portion of the solution after titrating the matter insoluble in alcohol (Section 18) containing not more than 0.2 g. silica and add 5 to 10 ml. of strong HCl.

(*c*) Evaporate the acidified solution (washing off and removing the cover glass if used) to dryness on a steam bath or hot plate at a temperature not exceeding 200 C. Cool, moisten with HCl (sp. gr. 1.19), let stand 5 to 10 min., breaking up all lumps with a stirring rod. Add about 25 ml. of hot water. Heat a few minutes and filter through a small ashless paper. Wash thoroughly with hot water.

(*d*) Evaporate the filtrate to dryness and repeat the above treatment, filtering on a second paper. Carefully ignite the two papers and contents in a weighed platinum crucible, first at a low temperature until the paper is consumed, then over a blast lamp. Cool in a desiccator, weigh and repeat until constant weight is obtained. If extreme accuracy is desired, moisten the weighed contents of the crucible with water, add 10 ml. of HF and four drops of strong H_2SO_4, evaporate to dryness over a low flame, ignite at the temperature of the blast lamp for about 2 min., cool in a desiccator, and weigh. The difference between this weight and the previous weight is the weight of the silica (SiO_2). To calculate sodium silicate having the ratio, 1 Na_2O:3.25 SiO_2, multiply the weight of SiO_2 by 1.308.

CARBON DIOXIDE (CARBONATES)

38. For most determinations the dry matter insoluble in alcohol and soluble in water as obtained in the determination of matter insoluble in alcohol (Section 15) will be suitable for this determination and the carbonates can be determined by direct titration of the water solution. In some cases it might be desired to run the test directly on an original sample of the soap. This should always be done when the highest accuracy is required. Any reliable absorption method for determining carbon dioxide may be used. A method which has proved satisfactory is described in the following Sections 39 and 40.

Apparatus Assembly

39. Place a 250-ml. Erlenmeyer flask on a gauze over a burner. Fit the flask with a two-hole rubber stopper, one opening to carry a 25-cm. (10-in.) reflux condenser and the other a thistle tube equipped with a three way stopcock. Draw out the end of the thistle tube to a small point, and place it in the stopper so that the point is very close to the bottom of the flask. Attach a small funnel to the straightaway end of the stopcock for the introduction of acid into the flask. Attach the other opening of the stopcock (which is to receive air) to a purifying tube containing soda-asbestos (ascarite) or any other suitable carbon dioxide absorbent. Attach to the top of the reflux condenser a train consisting of the following: (*a*) a drying tube containing a dehydrating agent such as sulfuric acid (sp. gr. 1.84) or magnesium perchlorate, (*b*) a weighed tube containing ascarite

and magnesium perchlorate, and a second weighed tube containing concentrated sulfuric acid. Attach to this train a protective U-tube containing calcium chloride; attach the U-tube to an aspirator.

Procedure

40. Set up the apparatus, leaving out the weighed train, and aspirate with a slow stream of the dry carbon dioxide-free air until the apparatus is free of carbon dioxide. Insert the train and continue to aspirate for 30 min. Check the weight of the train to determine whether the air is passing through too fast, or whether the system is free of carbon dioxide. The system must be free from leaks. Weigh out 1 or 2 g. of the sample into the Erlenmeyer flask, cover with 20 ml. of freshly boiled distilled water and close the apparatus with the train in place. Add 20 ml. of diluted HCl (1:1) very slowly through the funnel; do not apply heat to the flask. The rate of adding acid should be carefully controlled so that the gas does not pass through the train too rapidly. As soon as the acid is added, start aspiration gently. When the absorption begins to slacken, start heating gently and continue until the contents of the flask have boiled 15 to 20 min. Stop heating and continue aspirating until the flask has cooled down. Remove the train and weigh. The increase in weight represents carbon dioxide. The amount of this increase multiplied by 2.41 equals sodium carbonate.

PHOSPHATES

41. If a qualitative test has shown the presence of phosphates and their determination is desired, the matter insoluble in alcohol (Section 15) or the ash from the incineration of an original sample may be used. An original sample should always be used when the highest accuracy is desired.

Special Solutions Required

42. (*a*) *Molybdate Solution.*—Dissolve 100 g. of molybdic acid in diluted NH_4OH (144 ml. of NH_4OH (sp. gr. 0.90) and 271 ml. of water); pour this solution slowly and with constant stirring into dilute nitric acid (489 ml. of HNO_3 (sp. gr. 1.42) and 1148 ml. of water). Keep the final mixture in a warm place for several days or until a portion heated to 40 C. deposits no yellow precipitate of ammonium phosphomolybdate. Decant the solution from any sediment and preserve in glass-stoppered vessels.

(*b*) *Ammonium Nitrate Solution.*—Dissolve 100 g. of commercial ammonium nitrate, phosphate-free, in water, and dilute to 1 liter.

(*c*) *Magnesia Mixture.*—Dissolve 55 g. of crystallized magnesium chloride ($MgCl_2 \cdot 6H_2O$) in water, add 140 g. of ammonium chloride, 130.5 ml. of NH_4OH (sp. gr. 0.90), and dilute to 1 liter.

(*d*) *Diluted Ammonium Hydroxide for Washing.*—Dilute 100 ml. of NH_4OH (sp. gr. 0.90) to 1 liter.

Procedure

43. (*a*) Weigh out a 2-g. ± 0.01 g. sample of the alcohol-insoluble matter or ash and proceed as in the determination of alkaline silicates (Section 37) for removal of silica, saving the filtrate. Make up the filtrate to 250 ml. concentrating if necessary. Pipette an aliquot corresponding to 0.50 or 1 g. into a 250-ml. beaker; add NH_4OH in slight excess; and barely dissolve the precipitate formed with a few drops of HNO_3, stirring vigorously. Add about 15 g. of dry ammonium nitrate or a solution containing that amount. Heat to about 60 C. and add 70 ml. of the molybdate solution for every decigram of phosphoric acid (P_2O_5) present.

(*b*) Digest at about 65 C. for 1 hr. and determine whether or not the phosphoric acid has been completely precipitated by the addition of more molybdate solution to the clear supernatant liquid. Filter, and wash with cold water or preferably with the ammonium nitrate solution. Dissolve the precipitate on the filter with NH_4OH (1:1) and hot water and wash into a beaker to a volume of not more than 100 ml. Neutralize with HCl using litmus paper or bromthymol blue as an indicator, cool, and from a burette add slowly (about 1 drop per second), stirring vigorously, 15 ml of the magnesia mixture for each decigram of phosphoric acid (P_2O_5) present. After 15 min., add 12 ml. of NH_4OH (sp. gr. 0.90).

(*c*) Let the solution stand until the supernatant liquid is clear (2 hr. is usually enough), filter, wash the precipitate with the diluted NH_4OH until the washings are practically free from chlorides; dry, burn first at low heat and ignite to constant weight, preferably in an electric furnace, at 950 to 1000 C.; cool in a desiccator, and weigh as $Mg_2P_2O_7$. Calculate and report the result as percentage of P_2O_5 or alkaline phosphate known to be present.

SULFATES

Procedure

44. For most determinations the matter insoluble in alcohol obtained in Section 15 may suffice. If a determination of the highest accuracy is desired, ignite 10 g. ± 0.10 g. of the sample and use the ash from the ignition. Digest with 100 ml. of water, cover with a watch glass, and neutralize carefully with HCl. When neutralized, add 5 ml. excess of HCl, filter, and wash the residue thoroughly. (Evaporation to dryness is unnecessary unless gelatinous silica should have separated, and should never be performed on a bath heated by gas.) Make up the filtrate to 250 ml. in a beaker, and boil. To the boiling solution add 15 to 20 ml. of barium chloride solution (10 per cent) slowly drop by drop from a pipette. Continue boiling until the precipitate is well formed, or digest on a steam bath overnight. Set aside overnight or for a few hours, filter through a prepared Gooch crucible, ignite gently, and weigh as barium sulfate. Calculate to sodium sulfate, or alkaline sulfate known to be present.

GLYCEROL, SUGARS AND STARCH

Glycerol in the Absence of Sugars

Special Solutions Required

45. (*a*) *Potassium Bichromate Solution.*—Dissolve 74.553 g. of potassium bichromate in 500 ml. of water in a 1-liter volumetric flask. Dilute to the mark with water.

(*b*) *Sodium Thiosulfate Solution (0.1 N).*

(*c*) *Potassium Iodide Solution (10 per cent).*

Procedure

46. (*a*) Weigh a portion of the sample equivalent to not more than 3.0 g. of glycerol and dissolve in 200 ml. of hot water in a 600-ml. beaker. If starch is present, it will be necessary to remove the matter insoluble in water as described in Sections 15 and 17. Combine the alcohol and water solutions, evaporate off the alcohol, and proceed. Decompose with 25 ml. of H_2SO_4 (1:4). If alcohol is present, volatilize it by boiling for 20 to 30 min. Cool, remove, and rinse the cake of fatty acids, transfer the acid water and rinsings to a 500-ml. graduated flask, and add about 0.25 g. of silver sulfate to precipitate traces of chlorides and soluble fatty acids. Make up to volume and mix contents thoroughly.

(*b*) Transfer a filtered, accurately measured 50-ml. aliquot of the solution obtained in Paragraph (*a*) to a 400-ml. beaker, and to this add 75 ml. of accurately measured potassium bichromate solution, followed by 25 ml. of H_2SO_4 (sp. gr. 1.84), cover with a watch glass, and oxidize by heating to 90 to 100 C. for 3 hr. Conduct a blank in like manner but using 100 ml. of water, 25 ml. of H_2SO_4 (sp. gr. 1.84), and 25 ml. of accurately measured potassium bichromate. Cool and dilute the solutions to 1000 ml. in graduated flasks. The excess of potassium bichromate is determined by taking 50-ml. aliquots of the above, adding 50 ml. of water and 20 ml. of potassium iodide solution (10 per cent), and titrating the liberated iodine with 0.1 *N* thiosulfate, using starch solution as indicator.

(*c*) Calculate the percentage of glycerol (1 ml. of the potassium bichromate solution is equivalent to 0.0100 g. of glycerol).

Glycerol in the Presence of Sugars

Procedure

47. Proceed as in the determination of glycerol in the absence of sugar (Section 46), taking a sample so that the sum of the glycerol and sugar is not more than 3.0 g. (If starch is present, this must first be removed as described in Section 46.) The solution must be boiled in all cases at least 20 min. to ensure complete inversion of sucrose as in Section 50. Determine the amount of potassium bichromate solution required to oxidize

both the sugar and glycerol. Determine also the sugar by the method described in the determination of sugar (Sections 49 and 50).

Calculate the percentage of glycerol after deducting the amount of potassium bichromate required by the sugar.

1 ml. of potassium bichromate is equivalent to 0.0100 g. of glycerol
1 ml. of potassium bichromate is equivalent to 0.01142 g. of invert sugar

Starch

Procedure

48. (*a*) Separate the matter insoluble in water as in Section 17, using a sample of soap that will give not more than 3 g. of starch. Transfer the insoluble matter, without drying, to a beaker and heat for 2.5 hr. with 200 ml. of water and 20 ml. of HCl (sp. gr. 1.125) in a flask provided with a reflux condenser. Cool, and nearly neutralize the solution with NaOH. Make up the volume to 250 ml., filter, and determine the reducing sugars by the gravimetric method as described in the method for the determination of sugar (Section **50**).

(*b*) Calculate the amount of dextrose (*d*-glucose) equivalent to the cuprous oxide obtained. This multiplied by 0.90 equals the amount of starch.

Sugars

Apparatus and Solutions Required

49. The apparatus and solutions required shall be the same as those described in the standard Munson-Walker method.[1]

Procedure

50. Dissolve 10 g. ± 0.01 g. of the sample in 200 ml. of hot water in a 600-ml. beaker. Decompose with 25 ml. of H_2SO_4 (1:4), boil gently for 20 min. to invert the sucrose completely. Cool the solution, remove the heat, and rinse the cake of fatty acids. Extract the acid liquid with 25 ml. of ether. Neutralize the acid liquid with NaOH solution, transfer to a 500-ml. graduated flask, dilute to the mark, and mix thoroughly. Determine the invert sugar in 50 ml. of this solution by the Munson-Walker method.[1] To calculate sugar (sucrose) multiply the amount of invert sugar found by 0.95. (If starch is present, first remove as described in Section 46, and then proceed as above.)

VOLATILE HYDROCARBONS

51. This method requires a source of dry, oil-free steam which is passed through the sample treated with acid, sufficient to liberate the fatty acids from the soap. The steam is next passed through strong NaOH solution to scrub out any volatile fatty acids, while the volatile hydrocarbons are

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[1] Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, Sugar, and Sugar Products, Section XXXIV, Paragraph 28, p. 476, 4th Edition (1935).

condensed with the steam in a suitable arrangement which allows the excess water to flow away, leaving the volatile hydrocarbons in the measuring burette. The method may be applied to samples containing substances immiscible with water and volatile with steam. (For solvents heavier than water a Bidwell-Sterling tube should be used. (See Sections 11 to 13.))

Apparatus

52. The apparatus and its arrangement are shown in Fig. 2. The following are the important items:

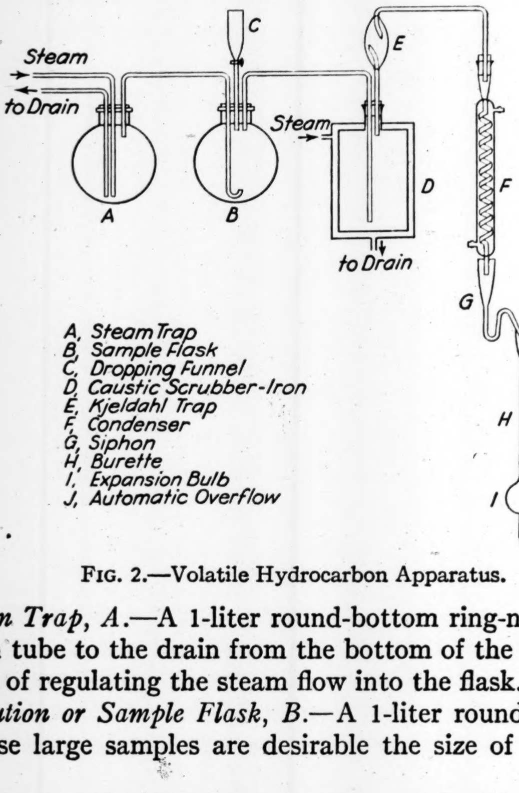
C
E
Steam
to Drain
Steam
D
F
A
B
to Drain
G
J
H
I
A, Steam Trap
B, Sample Flask
C, Dropping Funnel
D, Caustic Scrubber-Iron
E, Kjeldahl Trap
F, Condenser
G, Siphon
H, Burette
I, Expansion Bulb
J, Automatic Overflow

FIG. 2.—Volatile Hydrocarbon Apparatus.

(*a*) *Steam Trap, A.*—A 1-liter round-bottom ring-neck flask equipped with a siphon tube to the drain from the bottom of the flask and provided with a means of regulating the steam flow into the flask.

(*b*) *Evolution or Sample Flask, B.*—A 1-liter round-bottom ring-neck flask. In case large samples are desirable the size of this flask may be increased.

(*c*) *Caustic Scrubber Flask, D.*—A steam jacketed metal flask is preferred, but a 1-liter Florence flask provided with a steam coil of 0.32 cm. (0.125 in.) copper tubing around the upper half may be used. If the glass flask is used it should be provided with a safety bucket below it and should be renewed frequently since the strong caustic dissolves the glass rather rapidly. This flask should be connected to the condenser by a Kjeldahl connecting tube, *E*, or similar safety device.

The inlet for the steam into the evolution and scrubber flasks should extend nearly to the bottom of the flasks and bent at right angles and parallel to the sides of the flask.

(*d*) *Condenser, F.*—A 30.5-cm. (12-in.) or longer spiral condenser of sufficient bore so the condensate will not readily close it.

(*e*) *Measuring Burette, H.*—A 10-ml. burette calibrated to 0.1 ml. and carrying a bulb, *I*, of approximately 100-ml. capacity, at the lower end. If desired, an ordinary 10-ml. Mohr type burette may be used having attached to it by rubber tubing a bulb of proper capacity which has been blown in the laboratory. An ordinary burette funnel may be placed in the top of the burette in place of the special flared-out top shown in Fig. 2.

The stoppers used should be of a good grade of rubber and should have been thoroughly cleaned free from any surface sulfur and should be given a steam distillation in position for several hours before use on a sample.

Insulating the flasks and tubing to reduce condensation aids distillation and its control.

Procedure

53. (*a*) Place 150 ml. of NaOH solution (approx. sp. gr. 1.47) and several sticks of solid sodium hydroxide to provide against dilution in the scrubber flask. Rinse out the condenser and burette with acetone. Attach a rubber tubing to the lower end of the burette, fill the burette and tubing with water, and raise the outer end of the tubing so that the water level in the burette is near the top of the scale when the water is flowing to the drain from the automatic overflow, *J*. Be sure that the connections are tight and that the tubing contains no air bubbles. Place the condenser in position so that the lower end extends directly into the upper end of the burette just above the water level or connect to an adapter siphon, *G*, which discharges into the burette. The cooling water should be 15.5 C. or colder. Ice water may be desirable for low-boiling hydrocarbons.

(*b*) Weigh 100 g. ± 0.5 g. of the sample (cut into cubes of about 1-cm. edges) or 50 g. ± 0.3 g. of the sample of soap powder and transfer to the evolution flask (Note). Add about 10 g. of gum arabic (commercial) and 100 ml. of distilled water. Place the flask in position with 100 ml. of H_2SO_4 (1:3) in a dropping funnel, *C*, carried in the stopper. Connect with the steam and wash the flasks and the condenser, making sure that the stoppers are tightly fitting and held in place by wiring. Rubber connections in the lines between the evolution flask and condenser should be avoided.

(*c*) Add the acid to the sample slowly to avoid excessive frothing. While adding the acid, turn on the steam cautiously, so adjusting the pressure by a bleeder valve that just enough steam flows to prevent any liquid from backing into the steam trap flask.

(*d*) When all the acid has been added, turn on enough steam to cause brisk distillation, taking care that no liquid is carried over from the evolution and wash flasks and that the condenser water does not become warm.

(*e*) Continue the distillation until there is no increase in the volume of the upper layer for 45 min. or no small droplets can be noted in the condensate.

(*f*) When distillation is completed, shut off and drain the condenser water, and allow the steam to heat up the condenser to drive out the last traces of volatile hydrocarbon. Shut off the steam as soon as vapor begins to issue from the lower end of the condenser. Immediately open the stopcock of the dropping funnel to prevent NaOH being drawn into the evolution flask.

(*g*) Stopper the burette and allow its contents to come to room temperature or bring them to a definite temperature by immersing the burette for 1 to 2 hr. in a water bath held at 25 C.

(*h*) Read the volume of the upper layer to the nearest 0.01 ml. The volume multiplied by the specific gravity equals the weight of the volatile hydrocarbon. The specific gravity should be determined at the temperature at which the volume is read. A small Sprengel tube made of 3-mm. glass tubing is convenient for this purpose.

(*i*) *Calculation.*—Calculate the percentage of volatile hydrocarbons as follows:

$$\text{Volatile Hydrocarbons, per cent} = \frac{\text{Milliliters of volatile hydrocarbon} \times \text{sp. gr.}}{\text{Weight of sample in grams}} \times 100$$

NOTE.—For some samples the volatile hydrocarbon content may be so low that a larger sample than 50 or 100 g. is desirable. The size of the evolution flask may need to be increased if larger samples are used. The amount of water in the evolution flask and acid used should also be correspondingly increased.

COMBINED SODIUM AND POTASSIUM OXIDES

Special Solutions Required

54. (*a*) *Ammonium Chloride Solution.*—Dissolve 100 g. of NH_4Cl in 500 ml. of distilled water, add 5 to 10 g. of pulverized K_2PtCl_6, and shake at intervals for 6 to 8 hr. Allow the mixture to settle overnight and filter. (The residue may be used for the preparation of a fresh supply of ammonium chloride solution.)

(*b*) *Platinum Solution.*—Prepare a solution containing the equivalent of 1 g. of metallic platinum (2.1 g. of K_2PtCl_6) in each 10 ml. of solution. For materials containing less than 15 per cent of K_2O, a solution containing 0.2 g. of metallic platinum (0.42 g. of K_2PtCl_6) in each 10 ml. of solution is recommended.

Preparation of Sample

55. Weigh a 10 ± 0.01-g. sample and sinter it in an evaporating dish below a dull red heat. Leach the ash with hot water, filter into a 100-ml. volumetric flask, and wash the paper with three 5 to 10-ml. portions of hot water. Complete the ashing after returning the filter paper and residue

to the original dish and sintering as before. Excessive heating shall be avoided. Removal of most of the alkali present by thoroughly washing the ash with hot water before completion of the ashing will aid in preventing over-heating of the greater portion of the sample. Add a few drops of HCl (1:1) to the ash and wash the contents of the dish into the volumetric flask. Acidify the solution in the volumetric flask with HCl, dilute to 100 ml., mix thoroughly, and pass through a dry filter.

Procedure

56. Acidify an accurately measured 10-ml. aliquot of the solution obtained in Section 55 with a few drops of HCl and add 10 ml. of the platinum solution. Evaporate the solution on a water bath to a thick paste which will become solid on cooling to room temperature. Avoid exposure to ammonia fumes while heating the solution. Treat the residue with approximately 6 ml. of alcohol (80 per cent) and add 0.6 ml. of HCl (sp. gr. 1.19). Filter on a Gooch crucible and wash the precipitate thoroughly with alcohol (80 per cent) both by decantation and on the filter, continuing the washing until after the filtrate is colorless. Then wash the residue five or six times with 25-ml. portions of the ammonium chloride solution to remove the impurities from the precipitate. Wash again thoroughly with alcohol (80 per cent), dry the precipitate at 100 C. for 30 min., and weigh. Calculate the result as percentage of K_2O of potassium oxide known to be present.

NOTE.—For the conversion of K_2PtCl_6 to K_2O the factor 0.19376 may be used.

TENTATIVE METHODS OF TEST
FOR
PARTICLE SIZE OF SOAPS AND OTHER DETERGENTS[1]

A.S.T.M. Designation: D 502 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These methods cover the determination of the particle size of soaps and other detergents by the hand sieving and machine sieving methods.

Sieves

2. The sieves shall conform to the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[2]

Sampling

3. (*a*) Soaps shall be sampled in accordance with Sections 3 and 4 of the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460) of the American Society for Testing Materials.[3]

(*b*) Other detergents shall be sampled in accordance with the Tentative Methods of Chemical Analysis of Special Detergents (A.S.T.M. Designation: D 501 – 38 T) of the American Society for Testing Materials.[4]

Hand Sieving Method

Procedure

4. A nest of clean, dry sieves shall be used consisting of a 1680-micron (No. 12), 420-micron (No. 40), and a 149-micron (No. 100) sieve. A 100 ± 0.1 g. well-mixed sample shall be transferred, without previous drying, to the top sieve. The sieves shall be shaken simultaneously by hand with occasional tapping of the edge of the bottom sieve on a large rubber stopper or a flat, thick piece of rubber. When the portion of the soap passing through the bottom sieve (149-micron, No. 100 sieve) is less than 0.1 g. per min. of shaking (this can well be judged by sifting into a large, dark colored pan) the top sieve shall be removed and shaken separately

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

[2] See p. 1289.

[3] See p. 1212.

[4] See p. 1258.

over a clean, dark pan to be certain that no more of the residue will pass through. Any material passing through the 1680-micron (No. 12) sieve shall be place on the 420-micron (No. 40) sieve, using a small camel's hair brush to remove the material from the catch pan. The same procedure of sifting shall be repeated successively with the 420-micron (No. 40) sieve, and the 149-micron (No. 100) sieve. The portions retained on the 1680-micron (No. 12), 420-micron (No. 40), and 149-micron (No. 100) sieves, and the portion passing the 149-micron (No. 100) sieve, shall be carefully weighed.

NOTE.—At least duplicate particle size determinations shall be made and the average of the two tests used in the calculations.

Machine Sieving Method

Procedure

6. A nest of clean dry sieves shall be used consisting of a 1680-micron (No. 12), 420-micron (No. 40), and a 149-micron (No. 100) sieve. A 100 ± 0.1 g. well-mixed sample shall be transferred, without previous drying, to the top sieve. The nest of sieves shall be placed in a mechanically operated sieve shaker and the machine allowed to run for 10 min. The portions retained on the 1680-micron (No. 12), 420-micron (No. 40), and 149-micron (No. 100) sieves, and the portion passing the 149-micron (No. 100) sieve shall be carefully weighed.

NOTE.—At least duplicate particle size determinations shall be made and the average of the two tests used in the calculations.

Calculations

7. (*a*) The percentage of material retained on the 1680-micron (No. 12) sieve shall be calculated by dividing the weight of the residue on the sieve by the original weight of the sample and multiplying by 100.

(*b*) The percentage of the material retained on the 420-micron (No. 40) sieve shall be calculated by adding the weight of the residues retained on the 1680-micron (No. 12) sieve to the weight of the residue on the 420-micron (No. 40) sieve, dividing the sum by the original weight of the sample and multiplying by 100.

(*c*) The percentage of the material retained on the 149-micron (No. 100) sieve shall be calculated by adding the weight of the residues retained on all three sieves, dividing the sum by the weight of the original sample and multiplying by 100.

TENTATIVE METHODS OF CHEMICAL ANALYSIS
OF
SULFONATED (SULFATED) OILS[1]

A.S.T.M. Designation: D 500 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) These methods prescribe procedures for the chemical analysis of sulfonated (sulfated) oils.

(*b*) The analytical procedures appear in the following order:

		Section
Moisture	Method A. Water by Distillation with a Volatile Solvent.......	2 to 7
	Method B. Moisture and Volatile Matter by Hot-Plate Method	8 to 12
Organically Combined Sulfuric Anhydride	Method A. Titration Method....................	13 to 17
	Method B. Extraction-Titration Method.........	18 to 22
	Method C. Ash-Gravimetric Method (In the Presence of True Sulfonates)......................	23 to 26
Total De-Sulfated Fatty Matter	....	27 to 30
Total Active Ingredients	....	31 to 34
Unsaponifiable Non-Volatile Matter	....	35 to 39
Inorganic Salts	....	40 to 44
Total Alkalinity	....	45 to 47
Total Ammonia	....	48 to 50
Acidity as Free Fatty Acids	Method A. In the Absence of Ammonium or Triethanolamine Soaps or Both..............................	51 to 53
	Method B. In the Presence of Dark Colored Oils but in the Absence of Ammonium or Triethanolamine Soaps or Both (Brine Method).............................	54 to 56
	Method C. In the Presence of Ammonium and/or Triethanolamine Soaps..................................	57 to 59

MOISTURE

Method A. Water by Distillation with a Volatile Solvent

Scope

2. This method of analysis determines water existing in a sample of sulfonated (sulfated) oil by distilling the sample with a volatile solvent. The method is applicable only to sulfonated oils that do not contain the following: mineral acids, free sulfonic acids, or free sulfuric acid esters; or alkali hydroxides, carbonates or acetates; or alcohol, glycerol, diethylene glycol, acetone or other water-miscible volatile compounds.

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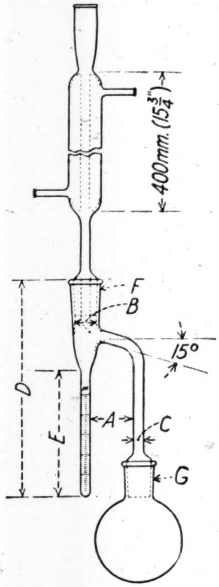
[1] Under the standardization procedure of the Society, these proposed methods are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

Apparatus

3. The apparatus required consists of a glass flask, heated by suitable means and provided with a reflux condenser, discharging into a trap and connected to the flask. The connections between the trap and the condenser and flask shall be interchangeable ground joints. The trap serves to collect and measure the condensed water and to return the solvent to the flask. A suitable assembly of the apparatus is illustrated in Fig. 1.

(*a*) *Flask.*—A 500-ml. flash of either the short-neck round-bottom type or the Erlenmeyer type shall be used.



A = 45 to 55 mm.
B = 22 to 24 mm., inside diameter
C = 9 to 11 mm., inside diameter
D = 235 to 240 mm.
E = 146 to 156 mm.
F and G are interchangeable joints, standard taper 24/40.

FIG. 1.—Apparatus for Determination of Water by Distillation with a Volatile Solvent, Method A.

(*b*) *Heat Source.*—The source of heat may be either an oil bath (stearic acid, paraffin wax, etc.) or an electric heater provided with a sliding rheostat, or other means of heat control.

(*c*) *Condenser.*—A water-cooled, reflux, glass condenser (Fig. 1), having a jacket approximately 400 mm. ($15\frac{3}{4}$ in.) in length with an inner tube 9.5 to 12.7 mm. ($\frac{3}{8}$ to $\frac{1}{2}$ in.) in outside diameter shall be used. The end of the condenser to be inserted in the trap shall be ground off at an angle of 30 deg. from the vertical axis of the condenser. When inserted into the trap, the tip of the condenser shall be about 7 mm. ($\frac{1}{4}$ in.) above the surface of the liquid in the trap after the distillation conditions have been established. Figure 1 shows a conventional sealed-in type of condenser, but any other condenser fulfilling the detailed requirements above may be used.

(*d*) *Trap.*—A trap made of well-annealed glass constructed in accordance with Fig. 1 and graduated as shown to contain 5 ml. at 20 C. shall be used. It shall be subdivided into 0.1-ml. divisions, with each 1-ml. line numbered (5 ml. at top). The error in any indicated capacity may not be greater than 0.05 ml.

Special Solutions Required

4. (*a*) *Xylene, c.p.*

(*b*) *Oleic Acid.*—Oleic acid, U.S.P. grade, heated previous to use for 5 to 10 min. over a free flame at a temperature of 130 to 135 C.

Calibration

5. To calibrate the apparatus add approximately 1 g. of water to a mixture of 80 g. of xylene and 10 g. of oleic acid. Conduct the distillation as described in Section 6 (*b*), (*c*), and (*d*). When all the water has distilled, cool the apparatus, add another gram of water, and repeat the distillation. Continue the calibration up to the capacity of the receiving tube.

Procedure

6. (*a*) Before using, clean the condenser and the receiving tube thoroughly with soap and warm water, rinse well, then treat with hot cleaning solution (a mixture of 10 ml. of saturated potassium bichromate and 990 ml. of H_2SO_4 (sp. gr. 1.84)), and finally thoroughly wash and dry.

(*b*) Take enough of the sample to be tested for analysis to yield about 4 ml. of water. Introduce the approximate quantity into a weighing bottle and make the weighings from the bottle into the flask, taking care that after removal of the sample, no drops of oil are left on the outside of the weighing bottle. Add 80 g. of xylene, and oleic acid equivalent to about two and one-half times the weight of the bone-dry sample, to prevent foaming and jellying of the contents of the flask. Introduce glass beads to prevent bumping and mix the contents of the flask thoroughly by swirling, care being taken to avoid any loss of material. Fill the trap with xylene and immediately connect the flask with the distillation apparatus; insert a loose cotton plug in the top of the condenser tube to prevent condensation of atmospheric moisture in the condenser tube.

(*c*) Heat the flask and regulate the heating so that the condenser tube immediately below the water-jacket is just barely hot. In this way a minimum of water will condense further up the condenser, where it may be difficult to volatilize any moisture condensed on the walls.

(*d*) Continue the distillation at the specified rate until practically no water is visible on any part of the apparatus except within the graduations of the trap. This operation usually requires less than an hour. Increase the rate of distillation in order to remove all traces of condensed water in the condenser tube and continue the distillation until the water level in the trap remains unchanged after a 10-min. interval. Dislodge any droplets adhering to the side of the receiver with a thin copper wire twisted into a loop. Immerse the receiving tube in warm water at about 40 C. for 15 min., or until the xylene layer becomes clear, then read and record the temperature and the exact volume of the water in the trap.

TABLE I.—SPECIFIC GRAVITY OF WATER.[a]

TEMPERATURE, DEG. CENT.	SPECIFIC GRAVITY
+ 4	1.00000
35	0.99406
36	0.99371
37	0.99336
38	0.99299
39	0.99262
40	0.99224
41	0.99186
42	0.99147
43	0.99107
44	0.99066
45	0.99025

---

[a] This table is taken from *Smithsonian Tables*, compiled from various authors.

Calculation

7. The volume of condensed water measured in the trap may be converted into its equivalent weight in grams by means of Table I. Calculate the percentage of water as follows:

$$\text{Water by weight, per cent} = \frac{\text{Grams of water}}{\text{Weight of sample in grams}} \times 100$$

Method B. Moisture and Volatile Matter by Hot-Plate Method

Scope

8. This method of analysis determines the percentage of water and other compounds volatile at about 100 C. existing in a sample of sulfonated (sulfated) oil by rapid evaporation. The method is applicable only to sulfonated oils that do not contain the following: mineral acids, free sulfonic acids or free sulfuric acid esters, ammonia, acetic acid or similar volatile acids, alkali hydroxides, carbonates, acetates or similar salts which may react with oleic acid at elevated temperatures liberating volatile acids, or glycerol, diethylene glycol, xylene or other compounds of similar volatility.

Apparatus

9. The apparatus required consists of a glass-stoppered weighing flask, a glass beaker, and a suitable thermometer.

(*a*) *Weighing Flask.*—Any suitable glass-stoppered weighing flask of 10 to 15-ml. capacity may be used.

(*b*) *Beaker.*—A Griffin low-form glass beaker with an approximate capacity of 150 ml. and a diameter of about 5 cm. shall be used.

(*c*) *Heat Source.*—The source of heat may be either an electric hot plate, with or without asbestos paper or board cover, or an open flame under a suitable asbestos board, and a wire gauze (to spread the heat).

(*d*) *Thermometer.*—A thermometer graduated from 90 to 150 C., about 3 in. in length, and substantially constructed shall be used.

Special Solutions Required

10. (*a*) *Oleic Acid, U.S.P.*

(*b*) *Desiccating Agent.*— Any suitable desiccating agent may be used.

NOTE.—Recent investigations seem to indicate that calcium chloride is unreliable as a laboratory desiccating agent.

Procedure

11. (*a*) Weigh approximately 5 g. of oleic acid, transfer it to the beaker and insert the thermometer. Heat the oleic acid gradually, while stirring with the thermometer, until the temperature reaches 130 C. Place the beaker in an oven at 105 to 110 C. for 15 min., cool in a desiccator, and weigh. Repeat the heating over the hot plate and in the oven until two successive weighings differ by less than 1.5 mg.

(*b*) Place about 6 g. of the sample in the weighing flask, and determine the weight accurately. Transfer the sample to the beaker (containing the thermometer), and weigh the flask again. Heat the mixture exactly as in the taring of the beaker as described in Paragraph (*a*). The loss in weight is equivalent to the moisture in the sample.

Calculation

12. Calculate the percentage of moisture and volatile matter in the sample as follows:

$$\begin{array}{c}\text{Moisture and volatile matter}\\ \text{(Hot-Plate Method), per cent}\end{array} = \frac{\text{Loss in weight of beaker in grams}}{\text{Weight of sample in grams}} \times 100$$

ORGANICALLY COMBINED SULFURIC ANHYDRIDE

Method A. Titration Method

Scope

13. This method of analysis determines the organically combined sulfuric anhydride existing in a sample of sulfonated (sulfated) oil by boiling the sample with sulfuric acid and determining the acidity of the reaction mixture. This method is applicable only to oils that split off their combined SO_3 upon boiling with mineral acids and that do not contain compounds which cannot be accurately titrated in water solution with methyl orange as the indicator.

Apparatus

14. The apparatus required consists of a glass flask provided with a glass stopper and an air condenser. The connection between the flask and the condenser shall be a ground joint. Perforated glass beads shall be used to prevent bumping.

(*a*) *Flask.*—An Erlenmeyer flask (Fig. 2) made of heat-resistant glass,[1] having a capacity of approximately 300 ml. and provided with a glass stopper shall be used.

(*b*) *Condenser.*—The condenser required consists of a glass tube, 915 mm. (36 in.) in length, and 8 mm. ($\frac{5}{16}$ in.) in outside diameter. The lower end of the tube shall be flared and ground to fit the mouth of the Erlenmeyer flask.

(*c*) *Glass Beads.*—Perforated glass beads, made of chemically-resistant glass, approximately 4 mm. ($\frac{5}{32}$ in.) in diameter shall be used. Before using, the glass beads shall be boiled thoroughly in several portions of water or until the wash-water reacts neutral to methyl orange indicator.

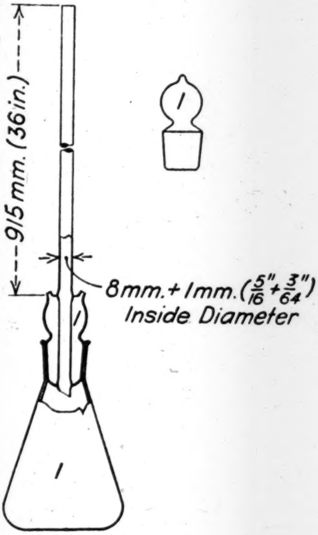


FIG. 2.—Apparatus for Determination of Organically Combined Sulfuric Anhydride, Method A.

The tolerance on the 8-mm. ($\frac{5}{16}$-in.) inside diameter tube is intended to be ± 1 mm. (± $\frac{3}{64}$ in.).

Special Solutions Required

15. (*a*) *Sodium Hydroxide* (*1 N*).—Accurately standardize a 1 *N* NaOH solution. Express the strength or concentration of the solution as milligrams of KOH per milliliter; 1 ml. of 1 *N* NaOH is equivalent to 56.1 mg. of KOH.

(*b*) *Sodium Hydroxide* (*0.5 N*).—Accurately standardize a 0.5 *N* NaOH solution. Express the strength of the solution as milligrams of KOH per milliliter; 1 ml. of 0.5 *N* NaOH is equivalent to 28.05 mg. of KOH.

(*c*) *Sulfuric Acid* (*Approximately 1 N*).

(*d*) *Sulfuric Acid* (*0.5 N*).—Accurately standardize a 0.5 *N* H_2SO_4

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[1] Pyrex glass is very satisfactory for this purpose.

solution. Express the strength of the solution as milligrams of KOH per milliliter; 1 ml. of 0.5 *N* H_2SO_4 is equivalent to 28.05 mg. of KOH.

(*e*) *Ethyl Ether, U.S.P.*

(*f*) *Sodium Chloride.*—Solid, c.p. NaCl.

(*g*) *Methyl Orange* (*0.1 per cent*).—Prepare a 0.1 per cent water solution of methyl orange indicator.

Procedure

16. The procedure consists of two determinations: namely, (*a*) the alkalinity of the sample, designated as *A*, and (*b*) the increase in acidity after boiling the sample with sulfuric acid, designated as *F*.

(*a*) *Alkalinity, A.*—Dissolve 10 g. of the sample in 100 ml. of water in the 250-ml. glass-stoppered Erlenmeyer flask, warming to obtain solution if necessary. After cooling, add 30 g. of NaCl, 25 ml. of ether, and five drops of methyl orange indicator, then add 0.5 *N* H_2SO_4, with frequent but gentle shaking until the mixture is slightly acid. Shake the contents of the flask vigorously, and complete the titration by adding first 0.5 *N* NaOH, several drops at a time, until the solution is alkaline, and then the acid, one or two drops at a time, until the endpoint is reached. Shake the solution vigorously after each addition of reagent. Drain burettes for 3 min. before readings are taken. Calculate the alkalinity, *A*, as follows:

$$A = \frac{(B \times D) - (C \times E)}{W}$$

where A = the total alkalinity in milligrams of KOH per gram,
B = the milliliters of acid,
C = the milliliters of alkali,
D = the strength of the acid in milligrams of KOH per milliliter,
E = the strength of the alkali in milligrams of KOH per milliliter, and
W = the weight of the sample in grams.

(*b*) *Increase in Acidity upon Boiling, F.*—Weigh 10 g. of the sample into the Erlenmeyer flask and boil for $1\frac{1}{2}$ hr. under the air condenser with 1 *N* H_2SO_4 using glass beads to prevent bumping. The volume of H_2SO_4 added shall be sufficient to neutralize the total alkalinity, *A*, of the sample plus 25 ml. in excess. Regulate the heating so that the solution boils rather vigorously but with very little evaporation taking place. At the end of the heating period, allow the contents to cool, wash the condenser with a spray of water from a wash-bottle, disconnect the condenser. Add 30 g. of NaCl, 25 ml. of ether, 50 ml. of water and five drops of indicator, and titrate the solution with 1 *N* NaOH to the same endpoint as in the total alkalinity titration, Paragraph (*a*). During the titration stopper the flask frequently and shake the contents of the flask thoroughly. Drain the burettes for 3 min. before readings are taken.

NOTE.—Reserve the titrated solution for the subsequent determination of total de-sulfated fatty matter (Sections 27 to 30).

Make a blank determination simultaneously with the sample, using the same amount and strength of the H_2SO_4, approximately the same weight of glass beads, and heating and titrating under the same conditions as the sample.

Calculate the increase in acidity upon boiling, F, as follows:

$$F = \frac{(S - B)\,N}{W}$$

where F = the increase in acidity upon boiling in milligrams of KOH per gram,

S = the milliliters of NaOH necessary to titrate the sample,

B = the milliliters of NaOH necessary to titrate the blank,

N = the strength of the NaOH expressed as milligrams of KOH per milliliter, and

W = the weight of the sample in grams.

The increase in acidity, F, may be negative, in which case retain the sign obtained from the above formula in the calculation in Section 17.

Calculation

17. Calculate the percentage of organically combined sulfuric anhydride as follows:

$$\text{Organically combined sulfuric anhydride, per cent} = 0.1426\,(A + F)$$

where 0.1426 = one tenth of the molecular ratio of SO_3:KOH,

A = the total alkalinity in milligrams of KOH per gram, and

F = the increase in acidity upon boiling, expressed as milligram of KOH per gram. Retain the sign of F as obtained in Section 16 (*b*).

Method B. Extraction-Titration Method

Scope

18. This method of analysis determines the organically combined sulfuric anhydride existing in a sample of sulfated oil by extracting the undecomposed sulfonated or sulfated fat and other fatty matter over an acidulated, concentrated salt solution, boiling the residue with sulfuric acid after evaporating the solvent, and titrating the products of reaction. This method is applicable only to sulfated oils that split off their combined SO_3 upon boiling with mineral acids, including samples containing sodium acetate or other compounds that cannot be accurately titrated in water solution with methyl orange as the indicator.

Apparatus

19. The apparatus shall be the same as described for Method *A* in Section 14.

Special Solutions Required

20. The solutions shall be the same as described for Method *A* in Section 15.

Procedure

21. The procedure consists of isolating and purifying the fatty matter as it exists in the original oil by dissolving the sample in a solvent, acidifying and washing with saturated brine, and determining the increase in acidity upon boiling the isolated product with sulfuric acid. This increase in acidity is designated as *F*.

(*a*) *Separation of Purified Oil.*—Weigh 5 to 10 g. of the sample, depending upon the concentration of the fatty matter, into a 250-ml. separatory funnel containing 50 ml. of concentrated NaCl solution, some solid NaCl, 5 drops of methyl orange indicator, and 50 ml. of ether. Shake the mixture and neutralize with approximately 1 *N* H_2SO_4 until the lower layer is distinctly pink (about 0.2 ml. in excess).

NOTE.—Highly sulfonated oils at this stage may form three layers instead of two. In such cases, use a fat solvent consisting of a mixture of two parts of ether and one of alcohol.

Allow the mixture in the separatory funnel to settle for at least 5 min., draw off the lower layer into another separatory funnel and wash the ether layer with 25-ml. portions of NaCl solution until practically neutral to methyl orange, that is, until 1 drop of 0.5 *N* NaOH turns the wash water strongly alkaline. Allow all separations to settle for at least 5 min. Combine the water layers, and extract with two 25-ml. portions of ether. Combine the last two ether extractions and wash with NaCl solution until free from acid, as in the case of the ether layer in the first funnel. Combine all the ether layers in the decomposition flask and evaporate the ether.

(*b*) *Increase in Acidity Upon Boiling, F.*—Determine the increase in acidity upon boiling in accordance with the procedure described for Method *A* in Section 16 (*b*). (See Note.)

NOTE.—Reserve the titrated solution for the subsequent determination of total de-sulfated fatty matter (Sections 27 to 30).

Make a blank determination as described for Method *A* in Section 16 (*b*).

Calculate the increase in acidity *F* in accordance with Section 16 (*b*).

Calculation

22. Calculate the percentage of organically combined sulfuric anhydride as follows:

$$\begin{array}{l}\text{Organically combined sulfuric anhydride}\\ \text{(Extraction-titration method), per cent}\end{array} = 0.1426 \times F$$

where 0.1426 = one tenth the molecular ratio of SO_3: KOH, and
F = the increase in acidity upon boiling.

Method C. Ash-Gravimetric Method (In the Presence of True Sulfonates)

Scope

23. This method of analysis determines the organically combined sulfuric anhydride existing in a sample of sulfonated oil by extracting the undecomposed sulfonated or sulfated fat and other fatty matter over an acidulated, concentrated salt solution, and ashing the purified extract. This method is applicable to all types of sulfonated oils, including true sulfonic acid oils and those containing sodium acetate or similar partially titratable compounds.

Special Solutions Required

24. (*a*) *Ethyl Ether, U.S.P.*

(*b*) *Sodium Chloride.*—Solid, c.p. NaCl.

(*c*) *Sodium Sulfate.*—Anhydrous, c.p. Na_2SO_4.

(*d*) *Methyl Orange (0.1 per cent).*—Prepare a 0.1 per cent water solution of methyl orange indicator.

Procedure

25. The procedure consists of isolating and purifying the fatty matter as it exists in the original oil by dissolving the sample in a solvent, acidifying and washing with saturated brine, and ashing the purified extract. If the sample contains ammonia, the ammonia shall first be expelled before the determination is made on the sample.

(*a*) *In the Absence of Ammonia.*—Proceed as described in the separation of purified oil (Section 21 (*a*)), combining the ether layers in the first funnel rather than in the decomposition flask. Carefully remove any water that may settle and dehydrate the ether layer as follows: add 5 g. of anhydrous Na_2SO_4, shake vigorously for 5 min., and filter directly into a 150-ml. beaker, placed in a bath of warm water. Wash the flask and filter with ether until free from fat (absence of oil stains on the filter paper after drying) and add the filtrate to the beaker. To avoid creeping of the oil, the volume in the beaker should at no time during the filtering and washing exceed 50 ml. (one-third full).

Evaporate the ether solution until the volume has been reduced to about 20 ml. and transfer the residue to a tared 50-ml. crucible (high form). Immerse the crucible in a 100-ml. beaker containing warm water until practically all of the ether has evaporated. Rinse the beaker with two 10-ml. and three 5-ml. portions of ether, respectively, or until all of the oil has been transferred to the crucible; allow each portion of rinsing ether to evaporate before the next rinsing is made. Burn gently the solvent-free residue, and finally ignite at a dull red heat to constant weight.

To prevent creeping of the oil and to hasten evaporation, stir the solution with a glass rod; before the oil is burned, wipe the rod clean with ashless filter paper and add the paper to the crucible. To oxidize traces of carbon or sodium sulfide that might form, moisten the ash with hydrogen peroxide (30 per cent) and again carefully ignite to constant weight. Calculate the percentage of ash as follows:

$$\text{Extracted ash, per cent} = \frac{\text{Weight of ash in grams}}{\text{Weight of sample in grams}} \times 100$$

(*b*) *In the Presence of Ammonia.*—Dissolve 5 to 8 g. of the sample in 80 ml. of water in a 300-ml. beaker. Add 10 ml. of 1 *N* NaOH and boil the solution gently until wet litmus paper no longer indicates ammonia. Cool the solution and transfer to a 300-ml. separatory funnel and add about 35 g. of solid NaCl or enough to make the final solution a 25 per cent NaCl solution. Add 5 drops of methyl orange and complete the neutralization, extraction, etc., in accordance with the procedure described in Paragraph (*a*).

Calculation

26. Calculate the percentage of organically combined sulfuric anhydride as follows:

$$\text{Organically combined sulfuric anhydride, per cent} = 1.1267 \times \text{percentage of the extracted ash}$$

where 1.1267 = the molecular ratio of $2SO_3:Na_2SO_4$.

TOTAL DE-SULFATED FATTY MATTER

Scope

27. This method of analysis determines the total de-sulfated fatty matter in a sample of sulfated oil by decomposition with diluted mineral acids and extraction of the decomposed fat. This method is not applicable to samples that are not completely decomposed upon boiling with mineral acids.

Special Solutions Required

28. (*a*) *Sulfuric Acid* (*Approximately 1 N*).

(*b*) *Ethyl Ether, U.S.P.*

Procedure

29. The procedure consists in decomposing the sample with sulfuric acid, extracting the fatty matter with ether, evaporating the solvent, and weighing the residue. After cooling, transfer the titrated solution obtained after determining organically combined sulfuric anhydride, in accordance with Method *A* or Method *B* (Sections 16 (*b*) or 21 (*b*)), into a 250-ml. separatory funnel and shake with 50 ml. of ether. Draw off the water

layer into another separatory funnel and extract twice with 25-ml. portions of ether. Wash the combined ether layers with 15-ml. portions of water until the wash water is neutral to methyl orange. Transfer the ether layer to a tared 150-ml. beaker, evaporate on the water bath until practically free from solvent, dry in a hot-air oven at 105 to 110 C. for 30 min., cool in a desiccator and weigh. Repeat the heating for 30-min. periods until constant weight is obtained.

NOTE.—Reserve the extracted fatty matter for the subsequent determination of unsaponifiable matter (Sections 35 to 39).

Calculation

30. Calculate the total de-sulfated fatty matter as follows:

$$\text{Total de-sulfated fatty matter, per cent} = \frac{\text{Weight of residue in grams}}{\text{Weight of sample in grams}} \times 100$$

TOTAL ACTIVE INGREDIENTS

Scope

31. This method of analysis determines the total active ingredients in a sample of sulfonated or sulfated oil as it exists in the original sample by extracting the undecomposed sulfonated or sulfated fat and other fatty matter over an acidified concentrated salt solution. Free alkali or alkali bound as soap is not included.

NOTE.—In the case of sulfated oils only, this determination may also be estimated by calculation (see Section 34 (*c*)) as it is equivalent to the sum of the de-sulfated fatty matter and neutralized organically combined sulfuric anhydride.

Special Solutions Required

32. (*a*) *Ethyl Ether, U.S.P.*

(*b*) *Sodium Chloride.*—Solid, c.p. NaCl.

(*c*) *Sodium Sulfate.*—Anhydrous, c.p. Na_2SO_4.

(*d*) *Methyl Orange* (*0.1 per cent*).—Prepare a 0.1 per cent water solution of methyl orange indicator.

(*e*) *Alcoholic Potassium Hydroxide* (0.5 *N*).—Accurately standardize a 0.5 *N* alcoholic KOH solution the strength of which shall be expressed as milligrams of KOH per milliliter; 1 ml. of 0.5 *N* alcoholic KOH is equivalent to 28.05 mg. of KOH.

Procedure

33. (*a*) The procedure consists of isolating and purifying the fatty matter as it exists in the original oil by dissolving the sample in a solvent, acidifying and washing with saturated brine, and weighing the purified extract. Proceed as described in the determination of organically combined sulfuric anhydride, Method *C*, in the absence of ammonia (Section 25 (*a*)), retaining the separated active ingredients in the 150-ml. beaker instead of transferring it to a crucible. Evaporate the filtrate to a total

volume of about 20 ml., add exactly 2 ml. of alcoholic KOH, mix the contents by swirling, and finally evaporate until practically free from ether.

NOTE.—With highly sulfonated oil, it may be necessary to add 5 to 10 ml. of the alcoholic KOH in order to stabilize the residue.

(*b*) Dry the residue at 108 to 112 C. for 1½ hr., cool in a desiccator, and weigh. Repeat the heating for 30-min. periods until constant weight is obtained.

Calculation

34. (*a*) *Correction for the Alkali Added.*—Calculate the correction for the alkali added as follows:

$$\text{Correction for alkali added, grams} = 0.0006791\ (\text{milliliters of KOH} \times S)$$

where 0.0006791 = the molecular ratio of (K – H) : KOH divided by 1000, and
S = the strength of the KOH in milligrams of KOH per milliliter.

(*b*) *Total Active Ingredients.*—Calculate the total active ingredients as follows:

$$\text{Total active ingredients, per cent} = \frac{\text{Weight of residue in grams} - \text{alkali correction}}{\text{Weight of sample in grams}} \times 100$$

(*c*) *Total Active Ingredients Calculation Method* (*Applicable to Sulfated Oils only*).—Calculate the total active ingredients by the calculation method which is applicable to sulfated oils only, as follows:

$$\text{Total active ingredients, per cent} = \text{Percentage of total de-sulfated fatty matter} + \left(\frac{NaSO_4-}{SO_3} \times \text{percentage of combined } SO_3\right)$$

or

$$\text{Total active ingredients, per cent} = \text{Percentage of total de-sulfated fatty matter} + 1.4875 \times \text{percentage of combined } SO_3$$

NOTE.—The factor 1.4875 is based on the assumption that the de-sulfated fatty matter becomes polymerized at the point where the SO_3 splits off and no hydroxyl groups are formed. If the latter are formed the factor becomes $\frac{NaSO_3 - 1}{SO_3} = 1.275$. Calculated results were in better agreement with actual determinations when the higher factor was used.

UNSAPONIFIABLE NON-VOLATILE MATTER

Scope

35. This method of analysis determines the unsaponifiable, non-volatile (above 80 C.) matter existing in a sample of sulfated oil by saponifying the de-sulfated fatty matter and extracting the unsaponifiable matter from the soap solution with ethyl ether.

Apparatus

36. *Saponification Flask.*—The apparatus required for the saponification consists of a glass flask provided with an air condenser and identical with the apparatus described in Method *A* for organically combined sulfuric anhydride (Section 14 (*a*) and (*b*)).

Special Solutions Required

37. (*a*) *Potassium Hydroxide Solution* (*0.5 N*).—Prepare an approximately 0.5 *N* aqueous KOH solution.

(*b*) *Alcoholic Potassium Hydroxide* (*0.5 N*).—Prepare an approximately but not less than 0.5 *N* alcoholic KOH solution.

(*c*) *Ethyl Ether, U.S.P.*

Procedure

38. The procedure consists in decomposing the sample with mineral acid, extracting the de-sulfated fatty matter, saponifying the latter, and extracting the unsaponifiable matter from the soap solution with ethyl ether.

(*a*) *De-Sulfated Fatty Matter.*—Determine the de-sulfated fatty matter as described in the determination of total de-sulfated fatty matter (Section 29).

(*b*) *Saponification.*—Accurately weigh 2 to 2.5 g. of the de-sulfated fatty matter in the flask, add 25 ml. of the alcoholic KOH and simmer the contents (without loss of alcohol) for 1 hr. with occasional swirling, over an electric hot plate or other source of heat.

(*c*) *Extraction.*—Transfer the contents of the flask to a 250-ml. separatory funnel and wash the flask several times with a total of 50 ml. of water, pouring it into the separatory funnel. Extract the solution, while still warm (about 30 C.), with 50 ml. of ether (rinse the saponification flask with the ether before adding it to the separatory funnel), shaking vigorously for about 1 min., and allow the layers to settle and clear. Draw off the lower layer in a second 250-ml. separatory funnel and extract in a similar manner with two 50-ml. portions of ether.

(*d*) *Preliminary Water Washing.*—Add 20 ml. of water to the combined ether layer, turn the separatory funnel and contents over gently about six times, and allow the layers to settle and clear. Draw off the lower layer and discard. Wash the ether layer twice more with 20-ml. portions of water, shaking vigorously after each addition.

(*e*) *Alkali and Water Washing.*—Add 20 ml. of 0.5 *N* KOH to the washed ether layer, turn the separatory funnel and contents over gently about six times, and allow the layers to settle and clear. Draw off the lower layer and discard. Wash the ether layer with 20 ml. of water, shaking vigorously. Continue washing with 20 ml. of 0.5 *N* KOH followed by 20 ml. of water, shaking vigorously after each addition, until the alkali layer upon strong acidification with HCl and settling for a few minutes is only faintly opalescent. Finally wash the ether layer with 20-ml. portions of water until the wash water is no longer pink to phenolphthalein.

(*f*) *Solvent Removal.*—Transfer the ether layer to a 150-ml. beaker (counter-balance the beaker if the amount of unsaponifiable matter is small and important) and evaporate over a hot-water bath until practically free of ether. Heat the beaker at 75 to 80 C. until constant weight is obtained.

NOTE 1.—A 30 per cent alcoholic solution by volume is the most satisfactory solution from which to extract the unsaponifiable matter.

NOTE 2.—If emulsions form, add 5 ml. of alcohol, pouring it down the side of the funnel.

NOTE 3.—It is important to maintain the volume of ether at not less than 150 ml., otherwise small quantities of unsaponifiable matter may be lost.

NOTE 4.—To check whether or not the unsaponifiable matter is free from fatty acids, dissolve the residue in 10 ml. of freshly boiled neutral alcohol and titrate with 0.1 *N* alcoholic KOH solution, using phenolphthalein as the indicator. Not more than 0.1 ml. should be required for neutralization. If more is required, the determination has not been carried out effectively and must be repeated.

Calculation

39. Calculate the unsaponifiable matter as follows:

$$\text{Unsaponifiable non-volatile matter, percent} = \frac{\text{Weight of residue in grams}}{\text{Weight of de-sulfated fatty matter in grams}} \times \text{percentage of de-sulfated fatty matter}$$

INORGANIC SALTS

Scope

40. This method of analysis determines in a sample of sulfonated oil the inorganic sulfates, chlorides, and all other salts that are insoluble in a mixture of oleic acid and carbon tetrachloride. The method consists in dehydrating the sample, dissolving in a solvent, filtering and weighing the residue. The presence of sodium acetate does not interfere with this method.

Apparatus

41. Either a Gooch crucible or filter paper may be used for filtering. Ignite the Gooch crucible in a larger crucible, supported by an asbestos ring and assembled as shown in Fig. 3. If filter paper is used, it may be a 9-cm. Whatman No. 40 or similar grade of ashless filter paper.

Special Solutions Required

42. (*a*) *Oleic Acid, U.S.P.*

(*b*) *Carbon Tetrachloride, U.S.P.*

(*c*) *Ethyl Ether, U.S.P.*

(*d*) *Asbestos.*—Asbestos fiber, alkali and acid washed.

Procedure

43. The procedure consists of dehydrating the sample, dissolving in a solvent, filtering, and igniting the residue. In the presence of ammonium salts, the residue is not ignited but only dried to constant weight.

(*a*) *In the Absence of Ammonium Salts.*—Weigh 3 to 5 g. of the sample and place in a 250-ml. beaker, add an approximately equal amount of oleic acid, and heat the mixture on an oil bath, while stirring constantly with a thermometer, at a temperature of 105 to 110 C. until practically free from water. Continue the heating until the temperature of the contents reaches 118 to 120 C., and maintain at that temperature for about 5 min. If the dehydrated sample upon cooling does not remain liquid, add more oleic acid. Dissolve the dehydrated sample in 100 ml. of CCl_4 warmed to 50 to 55 C., and filter through a counterpoised filter paper or a Gooch crucible.

Prepare the Gooch crucible by passing a thin emulsion of asbestos fiber in water through the crucible until a pad of about 2 mm. in thickness is formed. Dry the asbestos pad and ignite for 30 min. at first gently and finally more strongly. Then pass 75 ml. of CCl_4 through the crucible and again ignite the asbestos pad, cool in a desiccator, and weigh. Repeat the process of washing with CCl_4 until there is no further loss in weight.

Wash the residue with three 15-ml. portions of a solution of oleic acid in CCl_4 (2 per cent), then with six 15-ml. portions of hot CCl_4, and finally with two 15-ml. portions of ether or until the residue is free from oil. Take care that the top of the filter is thoroughly washed. Transfer the last traces of the residue to the filter by allowing the solvent to evaporate when the salts become free flowing. Dry the residue at 125 to 130 C. for 45 min., cool in a desiccator, and weigh. Ignite the residue at a dull red heat for 15 min., weigh, and repeat the ignition until constant weight is obtained.

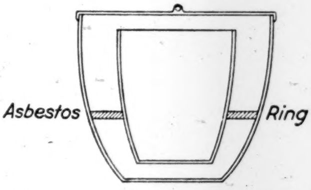

FIG. 3.—Gooch Crucible Assembly for Determination of Inorganic Salts.

(*b*) *In the Presence of Ammonium Salts.*—Proceed as described in Paragraph (*a*) for the determination of inorganic salts in the absence of ammonium salts with the following exceptions: (*1*) in preparing the Gooch crucible, do not ignite but heat it at 125 to 130 C. for 45 min., and repeat the heating until constant weight is obtained, and (*2*) heat the residue, whether in a Gooch crucible or on a filter paper as in (*1*), but do not ignite it.

Calculation

44. The method of calculation depends upon whether or not ammonium salts are present in the sample.

(*a*) Calculate the inorganic sulfates and chlorides including ammonium salts as follows:

$$\text{Inorganic sulfates and chlorides, including ammonium salts, per cent} = \frac{\text{Weight of dried residue in grams}}{\text{Weight of sample in grams}} \times 100$$

NOTE.—In the absence of ammonium salts, the difference between the percentage of the dried residue and the percentage of the ignited residue shall not be greater than 0.25 per cent.

(*b*) Calculate the non-volatile inorganic sulfates and chlorides (in the absence of ammonium salts) as follows:

$$\text{Non-volatile, inorganic sulfates and chlorides, per cent} = \frac{\text{Weight of ignited residue in grams}}{\text{Weight of sample in grams}} \times 100$$

TOTAL ALKALINITY

Scope

45. This method of analysis determines the total alkalinity existing in a sample of sulfonated and sulfated oil by titrating a water solution of the sample with mineral acid in the presence of methyl orange as the indicator. This method determines the total alkalinity of the fixed alkali, ammonia and triethanolamine bound as soap, free alkali, and the alkalinity of titratable alkaline salts, but not that of non-titratable alkaline salts.

Procedure

46. Proceed as described in the determination of alkalinity under organically combined sulfuric anhydride, Method *A* (Section 16 (*a*)).

Calculation

47. Calculate the total alkalinity as described in Section 16 (*a*)).

TOTAL AMMONIA

Scope

48. This method of analysis determines the total ammonia in a sample of sulfonated (sulfated) oil by boiling a water solution of the sample with excess alkali and determining by titration the loss in alkali after the boiling.

Procedure

49. The procedure consists of two determinations: namely, (*a*) the total alkalinity, and (*b*) the loss in alkalinity after boiling with excess NaOH.

(*a*) *Total Alkalinity.*—Determine the total alkalinity as described in the determination of organically combined sulfuric anhydride, Method *A* (Section 16 (*a*)).

(*b*) *Alkalinity After Boiling.*—Dissolve 10 g. of the sample in 100 ml. of water in a 500-ml. beaker, add 25 ml. of 0.5 *N* NaOH and boil the mixture for 30 min. or until all the ammonia is expelled as indicated by moistened red litmus paper. Cool the contents of the beaker, add methyl orange indicator (0.1 per cent) and titrate to an approximate endpoint. Transfer the mixture to a 250-ml. glass-stoppered flask and complete the titration (with the addition of salt and ether) as described in the determination of organically combined sulfuric anhydride, Method *A* (Section 16 (*b*)).

Calculation

50. Calculate the total ammonia as follows:

$$\text{Total ammonia, milligrams of KOH per gram} = A + \left(\frac{(B \times D) - (C \times E)}{W}\right)$$

or

$$\text{Total ammonia, per cent} = 0.0303\ (\text{total ammonia as milligrams of KOH})$$

where A = the total alkalinity in milligrams of KOH per gram,
B = the milliliters of alkali added,
C = the milliliters of acid added,
D = the strength of the alkali as milligrams of KOH per milliliter,
E = the strength of the acid as milligrams of KOH per milliliter, and
W = the weight of the sample in grams.

ACIDITY AS FREE FATTY ACIDS

Method A. In the Absence of Ammonium or Triethanolamine Soaps or Both

Scope

51. This method of analysis determines the acidity as free fatty acids existing in a sample of sulfonated and sulfated oil by titrating the sample dissolved in a solvent. It is not applicable in the presence of ammonium or triethanolamine soaps or salts, or other compounds which do not react neutral to phenolphthalein when dissolved in alcohol.

Procedure

52. The procedure consists of titrating a solution of the sample in a mixture of alcohol and ether in the presence of phenolphthalein indicator. Dissolve 10 g. of the sample in a mixture of 50 ml. of neutral alcohol and 25 ml. of ether, add five drops of phenolphthalein indicator, and titrate the solution with 0.5 N NaOH or KOH until the pink color persists after vigorous shaking.

Calculation

53. Calculate the acidity as free fatty acids, as follows:

$$\begin{array}{l}\text{Acidity as free fatty acids,}\\ \text{milligrams of KOH per}\\ \text{gram, calculated as acid}\\ \text{number}\end{array} = \frac{\text{Milliliters of alkali} \times \text{strength as milligrams of KOH}}{\text{Weight of sample in grams}}$$

Method B. In the Presence of Dark Colored Oils but in the Absence of Ammonium or Triethanolamine Soaps or Both (Brine Method)

Scope

54. This method of analysis determines the acidity as free fatty acids existing in a sample of sulfonated (sulfated) oil by titrating a water solution of the sample with phenolphthalein as the indicator. It is not applicable in the presence of ammonia or triethanolamine soaps or acid salts.

Procedure

55. The procedure consists in titrating a water solution of the sample in the presence of salt, ether, and alcohol with phenolphthalein as the indicator. Dissolve 10 g. of the sample in 100 ml. of water contained in a 250-ml., glass-stoppered, Erlenmeyer flask, warming to obtain solution, if necessary. After cooling, add 30 g. of NaCl, 25 ml. of ether and 50 ml. of neutral alcohol.

NOTE.—At this stage, methyl orange indicator may be added and the total alkalinity determined as described in the determination of organically combined sulfuric anhydride, Method *A* (Section 16 (*a*)).

Add five drops of phenolphthalein indicator (1.0 per cent alcoholic solution) and titrate the contents of the flask with 0.5 *N* NaOH until the first pink tinge appears in the water layer, shaking vigorously after each addition of the reagent.

Calculation

56. Calculate the acidity as free fatty acids as described in the determination of acidity as free fatty acids, Method *A* (Section 53).

NOTE.—In case the total alkalinity was determined on the same sample the free fatty acids is calculated as follows:

$$\begin{array}{l}\text{Acidity as free fatty}\\ \text{acids, milligrams KOH}\\ \text{per gram}\end{array} = \frac{\text{Milliliters of alkali} \times \text{strength as milligrams of KOH}}{\text{Weight of sample in grams}} - \left(\begin{array}{c}\text{total}\\ \text{alka-}\\ \text{linity}\end{array}\right)$$

Method C. In the Presence of Ammonium and/or Triethanolamine Soaps

Scope

57. This method of analysis determines the acidity as free fatty acids in the presence of ammonium and/or triethanolamine soaps, existing in a sample of sulfated or sulfonated oil or both, by calculation from the total alkalinity and the free-and-alkali-combined fatty acids.

Procedure

58. The procedure consists of two determinations: namely, (*a*) total alkalinity, and (*b*) free-and-alkali-combined fatty acids.

(*a*) *Total Alkalinity.*—Determine the total alkalinity as described in the determination of organically combined sulfuric anhydride, Method *A* (Section 16 (*a*)).

(*b*) *Free-and-Alkali-Combined Fatty Acids.*—Extract the total sulfated and sulfonated fatty matter as described in the determination of total active ingredients (Section 33 (*a*) and (*b*)), but omit the dehydration of the extract.

NOTE.–In the presence of acetates, wash the ether layer carefully with concentrated NaCl solution until one or two drops of 0.5 *N* NaOH added to the final wash water are neutral to phenolphthalein indicator.

Add exactly 0.5 ml. of 0.5 *N* NaOH to the extract, evaporate the ether to a volume of about 25 ml., add approximately 50 ml. of neutral alcohol, and titrate the mixture with 0.5 *N* NaOH.

Calculation

59. Calculate the free-and-alkali-combined fatty acids as described in the determination of acidity as free fatty acids, Method *A* (Section 53). Calculate the acidity as free fatty acids in the presence of ammonium and/or triethanolamine soaps, as follows:

$$\text{Acidity as free fatty acids, milligrams of KOH per gram} = (\text{Free-and-alkali-combined fatty acids}) - (\text{total alkalinity}).$$

TENTATIVE METHODS OF CHEMICAL ANALYSIS OF SPECIAL DETERGENTS[1]

A.S.T.M. Designation: D 501 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. These methods cover procedures for the chemical analysis of inorganic alkaline detergents.

CAUSTIC SODA

Sampling

2. (*a*) *Flake Caustic Soda.*—Flake caustic soda shall be sampled by removing portions from various parts of the drum.

(*b*) *Powdered Caustic Soda.*—Powdered caustic soda shall be sampled by inserting a sampling tube through the contents of the drum in several places. The tube shall be dried by heating just before use.

(*c*) *Fused Caustic Soda.*—Fused caustic soda shall be sampled by taking chipped samples from the center and bottom of the drum and then mixing the gross sample in the approximate proportions in which the tops and bottoms occur in the drum.

(*d*) *Precautions.*—Caustic soda shall not be sampled in a moist atmosphere. In the case of fused caustic soda the portion taken for analysis shall have the surface layer of carbonate scraped off immediately before transferring to the weighing bottle. In all cases the sample shall be transferred to a thoroughly dried weighing bottle immediately after it is taken; the bottle shall be tightly stoppered at once.

Total Alkalinity as Na_2O

3. Weigh 10 g. of the sample, dissolve in CO_2-free distilled water, wash into a 500-ml. volumetric flask and dilute to volume with CO_2-free distilled water. Protect the solution from the air as much as possible. Pipette a one-fifth aliquot into a 400-ml. beaker and determine Na_2O by titrating the sample against 1.0 N acid using methyl red as the indicator. Calculate the total alkalinity as Na_2O, as follows:

$$\text{Na}_2\text{O, per cent} = \frac{A \times 5 \times 3.1}{\text{Weight of sample in grams}}$$

where A = the milliliters of acid necessary to titrate the Na_2O in the sample.

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[1] Under the standardization procedure of the Society these proposed methods are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

Sodium Hydroxide

4. Determine the NaOH on a second one-fifth aliquot which is pipetted into a 250-ml. Erlenmeyer flask. Add about 25 ml. of neutral $BaCl_2$ solution (10 per cent) and titrate the sample with 1.0 *N* acid using phenolphthalein as the indicator. Calculate the percentage of NaOH as follows:

$$\text{NaOH, per cent} = \frac{B \times 5 \times 4.0}{\text{Weight of sample in grams}}$$

where B = The milliliters of acid necessary to titrate the NaOH in the sample.

Carbonate as Na_2CO_3

5. Calculate the carbonate as Na_2CO_3, as follows:

$$Na_2CO_3\text{, per cent} = \frac{(A - B) \times 5 \times 5.3}{\text{Weight of sample in grams}}$$

where A = the milliliters of acid necessary to titrate the Na_2O in the sample, and

B = the milliliters of acid necessary to titrate the NaOH in the sample.

NOTE.—When more accurate results are desired, one of the evolution methods for carbon dioxide should be used.

SODA ASH

Sampling

6. Soda ash shall be sampled by removing portions from various parts of the container. Samples shall not be taken from those portions of the soda ash where caking is noticeable due to the absorption of moisture and CO_2 through the container. If the soda ash is caked, the sample shall be obtained by thoroughly mixing and quartering the entire contents of the package.

Moisture

7. Determine the moisture content by drying 2.0 g. of the sample at 150 to 155 C. for 1 hr.

Total Alkalinity as Na_2CO_3

8. Analyses for carbonate and bicarbonate shall be referred to the dry basis or carried out on samples previously dried as described in Section 7. Weigh 5.3 g. of the sample and transfer to a 500-ml. Erlenmeyer flask. Dissolve the sample in 100 ml. of distilled water, add exactly 100 ml. of 1.0 *N* H_2SO_4 from a standard burette, place a small funnel in the neck of the flask, and boil gently for 5 min. to expel CO_2. Cool, rinse down the sides of the flask, add 4 drops of methyl red indicator and titrate with 0.1 *N* NaOH. Calculate the total alkalinity as Na_2CO_3, as follows:

$$\text{Total alkalinity as } Na_2CO_3\text{, per cent} = \text{Milliliters of acid} - \frac{\text{Milliliters of NaOH}}{10}$$

Sodium Bicarbonate

9. Weigh 8.4 g. of the sample and transfer to a 250-ml. beaker, dissolve in 100 ml. of distilled water, and titrate with 1.0 *N* NaOH until a drop of the solution added to a drop of freshly prepared $AgNO_3$ solution (10 per cent) on a spot plate gives a dark color instantly. Calculate the percentage of sodium bicarbonate as follows:

$$NaHCO_3\text{, per cent} = \text{Milliliters of } 1.0\ N\ \text{NaOH}$$

Calculate the percentage of Na_2CO_3 as follows:

$$Na_2CO_3\text{, per cent} = \text{Total alkalinity as } Na_2CO_3 \text{ in per cent} - (\text{percentage of } NaHCO_3 \times 0.6309)$$

Matter Insoluble in Water

10. Dissolve 20 g. of the sample in 300 ml. of distilled water in a 400-ml. beaker. Filter through a previously prepared, dried and weighed Gooch crucible. Wash the residue free from alkali with distilled water and dry in an oven at 100 C. Calculate the percentage of matter insoluble in water as follows:

$$\text{Matter insoluble in water, per cent} = \text{Weight of residue} \times 5$$

Apparent Density

11. Weigh 30 g. of the sample and transfer to a 100-ml. graduate. Rotate the graduate until the sample flows freely and then, taking great care to avoid jarring, level the surface of the sample, and read the volume. Calculate the apparent density as follows:

$$\text{Apparent specific gravity} = \frac{30}{\text{Volume in milliliters}}$$

$$\text{Apparent density, lb. per cu. ft.} = \text{Apparent specific gravity} \times 62.5$$

MODIFIED SODA (SESQUI-CARBONATE TYPE)

Sampling

12. The sample of modified soda (sesqui-carbonate type) shall be selected as described in Section 6 for the sampling of soda ash.

Total Alkalinity as Na_2O

13. Weigh 3.1 g. of the sample and dissolve in about 100 ml. of distilled water in a 500-ml. Erlenmeyer flask. Add 4 drops of methyl red indicator, and enough 1.0 *N* H_2SO_4 to reach the endpoint plus approximately 1 ml. in excess. Place a small funnel in the neck of the flask and boil for 5 min. to expel CO_2. The solution should still be acid after boiling. Rinse

down the sides of the flask and titrate back with 0.1 *N* NaOH. Calculate the total alkalinity as Na_2O, as follows:

$$\text{Total alkalinity as } Na_2O\text{, per cent} = \text{Milliliters of acid} - \frac{\text{Milliliters of NaOH}}{10}$$

Sodium Bicarbonate and Sodium Carbonate

14. (*a*) Weigh 8.4 g. of the sample and dissolve in about 100 ml. of distilled water in a 250-ml. beaker. Titrate the sample with 1.0 *N* NaOH until a drop of the solution added to a drop of freshly prepared $AgNO_3$ solution (10 per cent) on a spot plate gives a dark color instantly. Calculate the sodium bicarbonate as follows:

$$NaHCO_3\text{, per cent} = \text{Milliliters of 1.0 } N \text{ NaOH}$$

(*b*) ***Sodium** Carbonate*—Calculate the percentage of sodium carbonate as follows:

$$Na_2CO_3\text{, per cent} = (\text{Percentage of } Na_2O - \text{percentage of } NaHCO_3 \times 0.3690) \times 1.7097$$

Matter Insoluble in Water

15. Determine the matter insoluble in water in accordance with the procedure in Section **10**.

PHOSPHATES, SILICATES AND BORATES

Phosphates, Silicates, and Borates[1]

16. Determine these alkaline salts in accordance with the analytical procedures described in the Tentative Methods of Sampling and Chemical Analysis of Soaps and Soap Products (A.S.T.M. Designation: D 460 – 38 T) of the American Society for Testing Materials.[2]

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[1] The committee has in mind preparing more complete analytical procedures for these alkaline salts when the demand develops.

[2] See p. 1212.

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO SOAPS AND DETERGENTS[1]

A.S.T.M. Designation: D 459 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1937; REVISED, 1938.

Soap.—The product formed by the saponification or neutralization of fats, oils, waxes, rosins, or their acids with organic or inorganic bases.

Detergent.—Any material that aids in removing undesirable matter from the surface to be cleaned.

Alkaline Detergent.—A water soluble product, having an alkaline reaction and detergent qualities, but containing no soap.

Anhydrous Soap.—Pure soap free from water and all other concomitants.

Bar Soap.—Soap in the physical form stated.

Bead Soap.—Soap in the physical form stated.

Builder.—Any material added to soap to augment its efficiency.

Built Soap.—Soap containing one or more builders.

Bulk Soap.—Soap in the physical form stated.

Cake Soap.—Soap in the physical form stated.

Chip Soap.—Soap in the physical form stated.

Flake Soap.—Soap in the physical form stated.

Granulated Soap.—Soap in the physical form stated.

Liquid Soap.—Soap in the physical form stated.

Paste Soap.—Soap in the physical form stated.

Powdered Soap.—Soap in the physical form stated.

Soap Content.—The quantity of anhydrous soap present.

Solid Soap.—Soap in the physical form stated.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee D-12 on Soaps and Detergents.

TENTATIVE METHODS OF SAMPLING PLANT OR CONFINED WATERS FOR INDUSTRIAL USES[1]

A.S.T.M. Designation: D 510 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) Whenever water enters a conduit, pipe, or tank to be used in, or conveyed to, an industrial operation, it shall be regarded as a plant or confined water. The following recommendations refer specifically to sampling procedures for plant or confined water for industrial uses.[2]

(*b*) Normal variations in processes and in equipment from plant to plant preclude the possibility of specifying standard methods of sampling that will be applicable in all cases. Definite principles have, however, been established as a basis for the formulation of procedures for sampling which will be applicable in general and probably applicable in most specific cases. Where modifications of these procedures are necessary, they may be made by the exercise of trained judgment in each individual case.

GENERAL PRINCIPLES GOVERNING SAMPLING

General Rules for Sampling

2. The following general rules are applicable to all sampling methods:

(*a*) The samples shall be truly representative of the conditions existing at the point taken.

(*b*) The samples shall be of sufficient volume and shall be taken frequently enough to permit an accuracy of testing requisite for the object in view, as conditioned by the methods of analysis to be employed.

(*c*) The samples shall be collected, packed, shipped, and manipulated prior to analysis in a manner which will safeguard against change in the particular properties to be determined.

Tests to be Made and Quantity of Sample Required

3. The estimates in Table I cover the volume of sample required for the usual determinations that may be made upon a water sample as well as for several tests that may be made for special purposes.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

[2] Directions for sampling water intended for sanitary and domestic use may be found in "Standard Methods of Water Analysis," Eighth Edition, published by the American Public Health Assn. and the American Water Works Assn. (1936).

TABLE I.—VOLUME OF SAMPLE REQUIRED FOR DETERMINATION OF THE VARIOUS CONSTITUENTS OF INDUSTRIAL WATERS.

	VOLUME OF SAMPLE, ML.
PHYSICAL TESTS	
*‡Specific gravity	100
*‡Electrical conductivity	100
*Total dissolved solids	100 to 1000
*Suspended solids	50 to 1000
*Color and odor	50 to 1000
*Turbidity	100 to 100
CHEMICAL TESTS	
Dissolved Gases:	
†Oxygen, O_2	250 to 1000
†Total carbon dioxide, CO_2 (including CO_3^{--}, HCO_3^-, and free CO_2 if present)	100 to 200
†Total ammonia, NH_3 (as liberated by $KMnO_4$ and NaOH)	25 to 500
†‡Hydrogen sulfide, H_2S	500
†‡Free chlorine, Cl_2	100
†‡Hydrogen, H_2	1000
†‡Sulfur dioxide, SO_2 (includes SO_3^{--}, HSO_3^-, and free SO_2 if present)	100 to 200
Miscellaneous:	
Total hardness, soap or equivalent method	50 to 100
*Alkalinity, acidity and mineral acids	50 to 100
pH, Colorimetric	100
‡pH, Electrometric	100
Organic matter	50 to 1000
Silica	50 to 1000
R_2O_3, Al_2O_3 and Fe_2O_3	100 to 1000
Oily matter extractable by suitable solvents	500 to 2000
Metallic Ions:	
Iron, Fe^{++} and Fe^{+++}	100 to 1000
Aluminum, Al^{+++}	100 to 1000
†‡Ammonium, NH_4^+	25 to 500
‡Hydrogen, H^+	50 to 100
Calcium, Ca^{++}	100 to 1000
Magnesium, Mg^{++}	100 to 1000
Sodium, Na^+	100 to 1000
Potassium, K^+	100 to 1000
Manganese, Mn^{++} and Mn^{++++}	100 to 1000
‡Barium and Strontium, Ba^{++} and Sr^{++}	100
‡Copper, Cu^{++}	100 to 4000
‡Zinc, Zn^{++}	100 to 4000
‡Lead, Pb^{++}	100 to 4000
Nonmetallic Ions:	
*Carbonate, CO_3^{--}, HCO_3^-	100 to 200
*Hydroxide, OH^-	50 to 100
*Sulfate, SO_4^{--}, HSO_4^-	100 to 1000
‡Sulfite, SO_3^{--}, HSO_3^-	50 to 100
‡Sulfide, S^{--}, HS^-	100 to 500
Chloride, Cl^-	25 to 100
‡Other Halides, Br^-, I^-, F^-	25 to 100
Orthophosphate, PO_4^{---}, HPO_4^{--}, $H_2PO_4^-$	50 to 100
‡Nitrate, NO_3^-	10 to 100
‡Nitrite, NO_2^-	50 to 100

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* Aliquot may be used for other determinations.
† Sample must be obtained in separate container, completely filled and sealed against all exposure.
‡ Special test, not usually made.

Frequency and Duration of Sampling

4. A reasonably accurate estimate of the composition of a raw water piped from a large body of water, such as the Great Lakes, far enough from the shoreline to avoid variation from inflowing tributaries and sewage contamination, may be made by taking individual samples at infrequent intervals, such as bi-weekly or monthly. If taken from near the shoreline of such a body of water or from a river, samples should be taken at shorter intervals, for instance daily, to insure more exact knowledge of the variations in composition where these are of importance in the use to which the water is to be put. Where greater variations occur or closer control in plant intake water is required, more frequent samples shall be collected, say at hourly intervals.

Composite Samples

5. (*a*) Composite samples may be made by mutual agreement of the interested parties by combining individual samples taken at frequent intervals or else taken with an automatic sampler. In either case the volume of the samples shall be proportional to the rate of flow. At the end of a definite period the composite sample shall be thoroughly mixed, so that determinations on a sample of the composite will represent the average for the stable constituents.

(*b*) Variations of unstable constituents, for which individual samples are specified in Table I, shall be followed by analysis on the individual samples comprising the composite sample.

(*c*) In sampling process effluent waters, samples shall be collected over not less than one 24-hr. period. Composite samples preferably shall be collected over periods of 12 hr. or less. Increments for composite samples shall be collected at regular intervals from 15 min. to 1 hr., and shall be taken in proportion to the rate of flow of the effluent water. This may be conveniently done by taking a simple multiple in milliliters of the flow in second-feet or other unit of flow. A suitable factor shall be chosen to give the proper volume for the composite sample, which shall be about 4 liters.

Preservation of Samples

6. The addition of chemical preservatives to samples required for the determination of the normal mineral constituents is unnecessary.

NOTE.—Sulfuric acid is sometimes used, in a quantity to produce an acidity of 1000 p.p.m., to preserve samples for the determination of such constituents as nitrites and fatty matter. Ice is sometimes packed around special samples to preserve for a short time such constituents as carbon dioxide, but this can be done only for low concentrations.

Time Interval between Collection and Analysis of Samples

7. (*a*) In general, as short a time as possible shall elapse between the collection of a sample and its analysis. Under some conditions, analysis in the field is necessary to secure accurate results. The actual time which

may be allowed to intervene between the collection and analysis of a sample varies with the type of examination to be conducted, the character of the sample, and the time interval allowable for applying corrective treatment.

(*b*) On the statement of an analysis, the analyst shall specify the length of time elapsed between collection and analysis of confined industrial waters.

(*c*) The determination of dissolved gases, for instance, such as oxygen, hydrogen sulfide, and carbon dioxide, shall be made at the source, except that oxygen samples may be fixed at the time of taking and then analyzed as soon as possible.

GENERAL DIRECTIONS FOR SAMPLING

Containers for Samples

8. (*a*) In all cases, the container shall be chosen so that it shall not itself contaminate the sample, and it shall be cleaned thoroughly before being used in order to remove extraneous surface dirt.

(*b*) Water samples shall be collected in clean, narrow-mouth glass bottles, preferably glass-stoppered, although *new* cork stoppers may be used.

NOTE.—The use of tinfoil on corks is unnecessary, except where the samples, such as those containing oxidizing agents or those strongly acid or alkaline, are known to attack cork. The use of paraffin coatings is particularly to be avoided, as it is difficult to open a bottle with a stopper so coated without contaminating the sample with paraffin.

The silica content of highly alkaline water samples may be increased as a result of the action of the liquid on certain types of glass containers. The bottle glass should therefore be of a good chemically resistant type for waters having a pH of 6 or higher, or else the interior surface should be coated with paraffin. In cases where oil or organic matter is to be determined on the sample, paraffin shall not be used.

In locomotive practice, copper containers are sometimes preferable on account of breakage of glass containers.

Volume of Sample

9. The minimum volume of water to be furnished the analyst shall be 2 liters.

NOTE.—A sample of 4 liters is preferable and in some special cases, a sample as large as 20 liters may be necessary. The number of tests to be made and the amount required for each test by the procedure employed shall determine the size of the sample above the minimum specified. It is always desirable to have some of the sample left over for checking analyses or for further analyses at a later date.

Point of Sampling

10. (*a*) The point of sampling shall be chosen with extreme care so that a representative sample of the water to be tested will be obtained.

NOTE.—This may require experimentation in certain types of equipment, to determine the proper location of the sampling point with respect to the characteristics of the individual piece of equipment containing the water to be tested, the character and changes occurring between the incoming and outgoing water, and the rate of passage of water through the equipment. In certain industrial operations, overflow boxes, sumps, etc., are available from which samples may be taken, provided unstable constituents are not to be determined.

(*b*) Sampling cocks are often installed to take the sample at points on the equipment where it is desired to know the concentrations of the water constituents. Nozzles to such sampling cocks shall be inserted into the pipe line or piece of equipment to such a depth as to prevent pipe surface sampling. A point along the length of the pipe shall be chosen where there will be a minimum disturbance of flow due to fittings.

(*c*) Water-level or gage-glass petcocks or drain valves shall not be used as points of sampling in any type of container. Such samples are not representative of average concentrations in the vessel, as these are points of practically no circulation.

Rubber Tubing

11. If rubber tubing is used in the sampling line, it shall be sulfur-free and thoroughly washed, or else, if initially containing sulfur, it shall be boiled in caustic and thoroughly washed to remove dusting agents and "bloom."

Procedure in Taking Sample

12. (*a*) The faucet or valve from which the sample is to be drawn shall be provided with a rubber and glass tubing connection for the purpose of introducing the water at the bottom of the sample container.

(*b*) Before any water is introduced into the container, it shall first be allowed to flow to waste for a period adequate to insure freedom from inclusion in the sample of stagnant water or sediment, or both, from the pipe line.

(*c*) The rate of flow shall then be regulated to not more than 500 ml. per min. The maximum rate of flow shall not be great enough to permit the formation of entrained gas bubbles from dissolved gases present in the water as a result of pressure drop.

(*d*) A volume of water equal to at least ten times the volume of the sample container shall then be flowed into and overflowed from the latter before the sample is taken.

(*e*) Where contact with air would cause a change in the concentration of a constituent to be determined, the sample shall be taken out of contact with air and the container completely filled.

NOTE.—Samples for determinations of dissolved oxygen, carbon dioxide, and other gases; reducing agents, such as sulfite; and alkalinity require these precautions.

Cooling Hot Samples

13. Where samples of hot water are to be taken, cooling coils may frequently be used to cool the sample down to approximately room temperature. In all cases, such devices shall cool the sample to within at least 5 deg. of the temperature of the available cooling supply, or as near to 70 F. (21 C.) as possible. Corrosion-resistant materials chosen to suit the individual conditions shall be used for coils and tubing to conduct the sample from its source to the bottom of the sample bottle. The regu-

lating valve shall be on the discharge side of the cooler as close to the sampling outlet as possible.

NOTE.—This precaution is particularly applicable to the taking of oxygen samples, to avoid in-leakage of air at a defective joint or valve due to suction caused by the velocity of the water. To avoid trapping of noncondensable gases in the cooling coil, its position shall be upright and its size chosen to conform with inlet line and rate of flow.

Suspended Solids

14. (*a*) Normally, samples are secured without separation of suspended solids. Where constituents are present in colloidal and flocculent suspension, the sample shall be taken so that they are present in representative proportion.

NOTE.—Samples containing such materials are not normally affected by exposure to air, but on long standing sedimentation may occur.

(*b*) If it is desired to secure samples free of suspended matter from water at an elevated temperature, a filter shall be incorporated in a by-pass line to the cooling coil, and the sample shall be taken through this filter.

NOTE.—The reason for filtering the sample hot is to separate the suspended material on the filter before crystallization of dissolved material or re-solution of suspended material occurs due to the drop in temperature.

Labeling and Transportation of Samples

15. Immediately upon taking each sample a gummed label or a cardboard or linen tag, preferably a label, shall be securely affixed to the container and the following information noted thereon as soon as it becomes available:

Name of company supplying sample,
Name and location of plant,
Date and time of sampling,
Number of sample,
Source of sample or name and other designation of equipment sampled,
Point of sampling,
Pressure,
Temperature and rate of flow of the liquid in equipment from which the sample is taken,
Temperature of sample,
Results of field tests made on the sample, and
Signature of sampler.

(*b*) Stoppers, whether corks or glass, shall be wired, tied or taped down to prevent leakage in transit.

NOTE.—Paraffin, sealing wax or plaster of Paris shall be avoided for this purpose, as such a seal is hard to remove without contamination of the sample. A piece of tough paper placed over the stopper and held in place by a rubber band, twine or wire securely fastened around the neck of the container may be used.

(*c*) Samples to be shipped shall not fill the bottle entirely, unless absolutely necessary, in order to allow some room for expansion when subjected to a change in temperature.

NOTE.—An air space of 10 to 25 ml. usually suffices for this purpose, although this does not protect against bursting of the container due to freezing.

(*d*) The bottles shall be packed in cases with a separate compartment for each. Wooden boxes are preferred and shall be lined all around the bottles with corrugated paper, felt or similar materials, or provided with spring corner clips, or packed in sawdust, excelsior, or similar material, in order to minimize breakage.

(*e*) The samples shall be sent by express, provided they are packed according to express regulations. If sent by parcel post, the post office department regulations as to packing shall be adhered to, and some samples even then may not be accepted.

(*f*) The addresses of the consignee and of the consignor shall be plainly written upon two sides of the outer container or else firmly attached thereon by cards or labels. Labels, such as "Fragile," "Liquid," "Glass," "Handle with Care," "This Side Up," etc., shall also be attached to the outer container. In cold weather, the label, "Keep from Freezing," shall also be used.

TENTATIVE METHOD FOR DETERMINATION OF THE CALCIUM ION AND MAGNESIUM ION IN INDUSTRIAL WATERS[1]

A.S.T.M. Designation: D 511 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method covers the gravimetric determination of the calcium ion and the magnesium ion, the first by precipitation as calcium oxalate and ignition to calcium oxide, and the second by precipitation as magnesium ammonium orthophosphate and ignition to magnesium pyrophosphate. Directions for the preliminary removal of silica, iron, and aluminum are given, together with special directions for the removal of manganese, when necessary.

Application

2. The calcium ion and the magnesium ion present in any industrial water may be determined by this method.

Special Solutions Required

3. (*a*) *Hydrochloric Acid* (*sp. gr. 1.19*).—Concentrated HCl, reagent grade.

(*b*) *Diluted Hydrochloric Acid* (*1:1*).—Prepare a diluted HCl solution by adding one volume of the concentrated HCl (sp. gr. 1.19) to one volume of distilled water.

(*c*) *Nitric Acid* (*sp. gr. 1.42*).—Concentrated HNO_3, reagent grade.

(*d*) *Ammonium Hydroxide* (*sp. gr. 0.90*).—Concentrated NH_4OH reagent grade.

(*e*) *Diluted Ammonium Hydroxide* (*1:10*).—Prepare a diluted solution of NH_4OH by adding one volume of the concentrated NH_4OH (sp. gr. 0.90), reagent grade, to ten volumes of distilled water.

(*f*) *Diluted Ammonium Hydroxide* (*1:50*).—Prepare a diluted solution of NH_4OH by adding one volume of the concentrated NH_4OH (sp. gr. 0.90), reagent grade, to fifty volumes of distilled water.

(*g*) *Ammonium Oxalate*.—Prepare a solution, saturated at room temperature, from ammonium oxalate, reagent grade, and distilled water.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

(*h*) *Sodium Ammonium Hydrogen Orthophosphate.*—Prepare a solution, saturated at room temperature, from sodium ammonium hydrogen orthophosphate (microcosmic salt), reagent grade, and distilled water.

(*i*) *Ammonium Chloride* (*for Special Removal of Manganese*) (*2 per cent*).—Prepare a 2 per cent solution from NH_4Cl, reagent grade, and distilled water.

(*j*) *Methyl Red Indicator.*—Prepare a solution of methyl red by rubbing 0.100 g. of the indicator in an agate mortar with 7.4 ml. of 0.05 *N* NaOH solution until it has dissolved, rinsing out with distilled water, and diluting to 100 ml.

Procedure

4. (*a*) *Volume of Sample.*—The volume of water sample used for the determination of calcium and magnesium may be chosen on the basis of the content of total dissolved solids, as follows:

TOTAL DISSOLVED SOLIDS, P.P.M.	VOLUME FOR DETERMINATION, ML.
less than 50	4000
50 to 500	1000
more than 500	500

(*b*) The volume of the sample used shall be measured at 20 C. by means of a volumetric flask.

5. (*a*) *Removal of Silica.*—The measured volume of the water shall be acidified by adding 1 to 2 ml. of concentrated HCl (sp. gr. 1.19), and shall then be evaporated to dryness.

NOTE.—During evaporation the walls of the container should be moistened to avoid retention of silica.

(*b*) To the dry residue 2 ml. of diluted HCl (1:1) shall be added, the solution shall be diluted to approximately 75 ml. with distilled water and heated to boiling.

(*c*) The silica residue shall be filtered off and shall be washed on the filter paper with at least two successive additions of hot diluted HCl (1:1) and then with at least three successive additions of hot water, the washings being added to the filtrate.

6. (*a*) *Removal of Iron, Aluminum, and Manganese.*—In all cases when the special removal of manganese is unnecessary, the regular procedure as described in Paragraph (*c*) shall be followed.

(*b*) If the amount of manganese present in the water is known to be significantly large with respect to the magnesium, or if possible error in the magnesium determination due to manganese is to be avoided, the special procedure as described in Paragraph (*d*) shall be followed.

(*c*) *Regular Removal of Iron and Aluminum.*—The combined filtrate and washings procured under Section 5 (*c*) shall be heated to boiling and a few drops of concentrated HNO_3 (sp. gr. 1.42) shall be added. The solution shall be cooled, a few drops of methyl red indicator shall be added, and concentrated NH_4OH (sp. gr. 0.90) shall then be added until the solution has turned distinctly yellow. The solution shall be boiled for 2 min. and the precipitated iron and aluminum hydroxides shall be filtered off and washed on the filter with three successive additions of hot water.

(*d*) *Special Removal of Manganese with Iron and Aluminum.*—To the combined filtrate and washings procured under Section 5 (*c*) shall be added 1 g. of ammonium persulfate, and diluted NH_4OH (1:10) shall then be added until the solution is definitely ammoniacal. The solution shall be boiled for at least 15 min., with frequent additions of diluted NH_4OH (1:10) to maintain a slight excess alkalinity, and shall then be allowed to cool for from 10 to 15 min. The precipitate shall be filtered off and washed twice with NH_4Cl solution and at least three times with hot water.

7. (*a*) *Precipitation of Calcium Oxalate.*—To the filtrate procured under Section 6 (*c*) or (*d*) shall be added approximately 10 ml. of concentrated NH_4OH (sp. gr. 0.90) and the solution shall be heated to the boiling point, but shall not be allowed actually to boil.

(*b*) To the solution at the boiling point shall be added, drop by drop, saturated ammonium oxalate solution in excess. The solution shall be held at the boiling point for several minutes, and shall then be maintained at from 80 to 90 C. for at least 2 hr. before filtration.

(*c*) The precipitate of calcium oxalate shall be filtered off and washed on the filter with at least three successive additions of diluted NH_4OH (1:10).

NOTE.—If magnesium is to be determined, the combined filtrate and washings should be reserved.

8. (*a*) *Reprecipitation of Calcium Oxalate.*—The precipitate shall be dissolved and washed into the original beaker in which it was precipitated by the addition of a few milliliters of diluted HCl (1:1) to the filter, and the paper shall be washed sparingly with at least three successive additions of hot distilled water.

(*b*) To the solution from the preceding operation shall be added a few drops of methyl red indicator. Concentrated NH_4OH (sp. gr. 0.90) shall then be added until the solution has turned distinctly yellow, and the solution shall be heated to the boiling point.

(*c*) The operations of precipitating, filtering, and washing calcium oxalate as given in Section 7 (*b*) and (*c*) shall then be repeated.

NOTE.—If magnesium is to be determined, the combined filtrate and washings procured under Paragraph (*c*) should be added to those previously reserved from the operation of Section 7 (*c*).

9. *Ignition of Precipitate.*—The filter paper and its contents shall be ignited to constant weight in a platinum crucible at a temperature between 1100 and 1200 C.

NOTE 1.—The absorption of sulfur oxides from the flames of gas high in sulfur impinging on the crucible during ignition must be avoided.

NOTE 2.—The crucible should be cooled after ignition in a desiccator containing concentrated H_2SO_4.

NOTE 3.—The hygroscopic nature of calcium oxide should be kept in mind during weighing.

10. (*a*) *Precipitation of Magnesium Ammonium Orthophosphate.*—The combined filtrates and washings procured under Section 7 (*c*) and 8 (*c*) shall be made acid with concentrated HCl (sp. gr. 1.19), an excess of a saturated solution of sodium ammonium hydrogen orthophosphate shall be added, and the solution shall be evaporated slowly until a precipitate begins to crystallize.

(*b*) To the hot solution shall be added concentrated NH_4OH (sp. gr. 0.90), drop by drop, with constant stirring, until approximately 5 ml. more than the amount required to make the solution definitely ammoniacal is present. Stirring shall be continued for several minutes until precipitation is complete, and the precipitate shall be allowed to stand for at least 4 hr. at room temperature.

(*c*) The precipitate shall be filtered off and washed ten times on the filter paper with diluted NH_4OH (1:10).

11. (*a*) *Reprecipitation of Magnesium Ammonium Orthophosphate.*—The precipitate shall be washed back into the original beaker with cold water, and shall be dissolved with hot diluted HCl (1:1).

(*b*) The operations of precipitating, filtering, and washing magnesium ammonium orthophosphate, as given in Section 10 (*b*) and (*c*) shall then be repeated, using 1 to 2 ml. of the saturated solution of sodium ammonium hydrogen orthophosphate, and washing finally with diluted NH_4OH (1:50) in place of NH_4OH (1:10).

(*c*) *Ignition of Precipitate.*—The filter paper and its contents shall be dried and then ignited to constant weight.

Calculation

12. The concentrations of calcium ion and of magnesium ion in terms of parts per million shall be calculated as follows:

$$Ca^{++} = W_c \times \frac{714,600}{S}$$

where W_c = the weight of CaO in grams, and
S = the volume of sample in milliliters.

$$Mg^{++} = W_m \times \frac{218,400}{S}$$

where W_m = the weight of $Mg_2P_2O_7$ in grams, and
S = the volume of sample, in milliliters.

TENTATIVE METHOD FOR DETERMINATION OF THE CHLORIDE ION IN INDUSTRIAL WATERS[1]

A.S.T.M. Designation: D 512 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. This method covers the volumetric determination of chloride ion by titration of the sample with a solution of silver nitrate in the presence of potassium chromate as an internal indicator. A double titration is specified to obviate end point error. Directions for clarifying samples of high turbidity or color, or both, and for eliminating the interference of sulfite are given.

Application

2. Chloride ion present in industrial waters ranging from surface supplies to brines may be determined by this method. The ions normally present in such waters do not interfere, with the exception of sulfite which may readily be eliminated. Bromide and iodide, when present, are determined as chloride by this method.

Special Solutions Required

3. (*a*) *Silver Nitrate.*—Crush 2.5 to 3 g. of $AgNO_3$ crystals, reagent grade, and dry to constant weight either in a desiccator or in a drying oven at 30 to 40 C. Weigh 2.3955 ± 0.0005 g. of the dried $AgNO_3$, dissolve in chloride-free distilled water, and dilute with chloride-free distilled water to 1 liter at 20 C. One milliliter of this solution is equivalent to 0.0005 g. of the chloride ion. In case of controversy, the solution of silver nitrate shall be standardized against sodium chloride prepared as described in Paragraph (*b*), using the procedure specified in Section 6.

NOTE.—Since this solution deteriorates when exposed to light it should be protected during storage.

(*b*) *Sodium Chloride.*—In case standardization of the $AgNO_3$ solution is required, fuse approximately 20 g. of NaCl, reagent grade, in a platinum crucible, and cool in a desiccator. Crush the crystals and immediately after crushing, dissolve 16.4858 ± 0.0005 g. of the freshly fused sodium chloride in chloride-free distilled water and dilute to 1 liter at 20 C. Dilute one part by volume at 20 C. of the prepared solution with chloride-free distilled water to a volume of 100 parts at 20 C. One milliliter of this diluted solution is equivalent to 0.0001 g. of chloride.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

NOTE.—Thus 10 ml. may be diluted to 1 liter, or 50 ml. to 5 liters.

(*c*) *Potassium Chromate Indicator.*—Dissolve approximately 50 g. of neutral potassium chromate, reagent grade, in 100 ml. of distilled water, and add $AgNO_3$ until a slight red precipitate is produced. Allow the solution to stand protected from light, for at least 24 hr. after the addition of $AgNO_3$. Then filter the solution to remove the precipitate and dilute to 1 liter with distilled water.

(*d*) *Aluminum Hydroxide Coagulant.*—Dissolve approximately 125 g. of potassium alum, reagent grade, in 1 liter of distilled water. Precipitate $Al(OH)_3$ from this solution, by the cautious, progressive addition of NH_4OH. Separate the precipitated $Al(OH)_3$ from the solution by filtration, and wash with distilled water until free from chloride and ammonia. Store in chloride-free distilled water.

(*e*) *Hydrogen Peroxide* (*for sulfite removal*)(*30 per cent*).—Chloride-free hydrogen peroxide (30 per cent) shall be obtained when water containing sulfite is to be tested.

Preparation of Sample

4. (*a*) *Concentration or Dilution.*—If the concentration of chloride ion in the sample is so high that a preliminary titration requires more than 10 ml. of $AgNO_3$ solution for 50 ml. of water, a carefully measured portion of the sample shall be diluted with chloride-free distilled water to a known larger volume chosen so that 50 ml. of the diluted sample will then require from 5 to 10 ml. of $AgNO_3$ for titration.

(*b*) If the concentration of chloride ion in the sample is so low that a preliminary titration requires less than 1 ml. of $AgNO_3$ solution for 50 ml. of water, an adequately large and carefully measured portion of the sample shall be concentrated by evaporation to a smaller volume chosen so that 50 ml. of the concentrated sample will then require from 5 to 10 ml. of $AgNO_3$ for titration. If evaporation is necessary, it shall be so conducted that no loss by spattering or adherence of residual solid to the evaporating vessel occurs and no extraneous chloride is introduced by any possible contamination.

5. (*a*) *Removal of Turbidity or Color.*—If the turbidity or color, or both, of the sample is so great as to obscure or render uncertain the potassium chromate indicator end point, the sample shall be treated with $Al(OH)_3$, prepared as described in Section 3 (*d*).

(*b*) In clarifying a sample, a small amount of the well-shaken suspension of $Al(OH)_3$ shall be thoroughly mixed with the measured sample and then separated by filtration and washed on the filter with chloride-free distilled water.

(*c*) Clarification with $Al(OH)_3$ shall be employed only on samples of such extreme turbidity or color, or both, that a satisfactory end point cannot otherwise be obtained. The minimum amount of $Al(OH)_3$ which will produce adequate clarification shall be used.

6. *Removal of Sulfite.*—If sulfite is suspected to be present in the water, 2 ml. of chloride-free hydrogen peroxide (30 per cent) shall be added to each 50-ml. portion prior to analysis.

Procedure

7. (*a*) Two portions, one representing 50 ml. and the other 25 ml. of the original water, or of this water diluted or concentrated as described in Section 4 (*a*), shall be separately clarified, if necessary, as described in Section 5, and shall then be transferred respectively to two duplicate porcelain casseroles of matched whiteness. To the 25-ml. portion shall be added 25 ml. of chloride-free distilled water. If necessary, each portion shall then be treated to eliminate sulfite as described in Section 6.

(*b*) Each of the two portions shall be separately adjusted to a pH of 9.0 ± 0.2, using solutions of reagent grade H_2SO_4 or Na_2CO_3 of suitable concentration as required. The pH may be measured either colorimetrically with a comparator or electrometrically with an apparatus which does not include a salt bridge.

(*c*) To each portion of the sample shall be added 1 ml. of chromate indicator solution. Each portion shall then be titrated to the same pink end point with the $AgNO_3$ solution, using either a yellow light source or yellow goggles, and the volume of the solution required in each case shall be recorded.

NOTE.—A colorimeter may be used to advantage in matching the end points of the two portions.

Calculation

8. The concentration of chloride ion in the original sample in parts per million shall be calculated as follows:

$$Cl^- = \frac{1000\,(V_1 - V_2)}{S}$$

where V_1 = the milliliters of $AgNO_3$ solution required for 50-ml. portion,
V_2 = the milliliters of $AgNO_3$ solution required for 25-ml. portion, and
S = the milliliters of original water in 50-ml. portion.

NOTE.—If sample has been diluted to five times its volume, $S = \frac{50}{5} = 10$, while if sample has been concentrated to one tenth its volume, $S = 50 \times 10 = 500$.

TENTATIVE METHOD FOR DETERMINATION OF TOTAL CARBON DIOXIDE AND CALCULATION OF THE CARBONATE AND BICARBONATE IONS IN INDUSTRIAL WATERS[1]

A.S.T.M. Designation: D 513 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) Ordinary titration methods do not suffice to indicate the actual concentration of bicarbonate and carbonate ions in a sample of water. It is possible, however, to determine the total carbon dioxide content of a solution, and from this value to calculate the concentration of bicarbonate and carbonate ions at room temperature, provided the pH of the solution is known.

(*b*) This method for total carbon dioxide obviates interference by ions such as silicate, phosphate, chromate, and aluminate which affect the accuracy of direct titration methods. Carbonates are decomposed by an excess of acid and the carbon dioxide evolved from solution is absorbed in a barium hydroxide solution whose acid equivalent is known. After the absorption of carbon dioxide the residual barium hydroxide is titrated with standard acid and from the value for total carbon dioxide thus determined, with the aid of a separately determined pH value, the concentrations of carbonate and bicarbonate ions are calculated.

Application

2. This method is applicable to the analysis of all industrial waters, except those containing sulfides, sulfites, or other salts of volatile acids.

Apparatus

3. A recommended form of apparatus is illustrated in Fig. 1. It shall consist of a box, open at the front, painted internally with a flat white paint and suitably illuminated. Upon this box three 50-ml. burettes shall be mounted non-rigidly by means of rubber stoppers fastened to the under side of the top. A small circulating pump sealed with mercury shall be connected as shown so that when the flasks are attached to the stoppers of burettes *B* and *C*, a closed system is established.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

Special Solutions Required

4. (*a*) *Sulfuric Acid* (*0.1 N*).—Prepare an 0.1 *N* solution of H_2SO_4 from concentrated acid (sp. gr. 1.84), reagent grade, and standardize.

(*b*) *Hydrochloric Acid* (*0.02 N*).—Prepare an 0.02 *N* solution of HCl from concentrated acid (sp. gr. 1.19), reagent grade, and standardize. Add 20 ml. of phenolphthalein solution to 1 liter of the acid before it is standardized.

(*c*) *Barium Hydroxide* (*0.02 N*).—Prepare an approximately 0.02 *N* solution of barium hydroxide from $Ba(OH)_2 \cdot 8H_2O$, reagent grade. The acid equivalent of this solution shall be determined by using the evolution apparatus (Fig. 1). A 50-ml. sample of barium hydroxide solution shall be measured from burette *A* into absorption flask *E*, which shall then be securely attached to the rubber stopper on burette *B*. Then 200 ml. of carbon dioxide-free distilled water shall be placed in flask *D*, the pump started, and the gas circulated for about 10 min. The barium hydroxide in flask *E* shall then be titrated with standard 0.02 *N* HCl from burette *B* to the phenolphthalein end point.

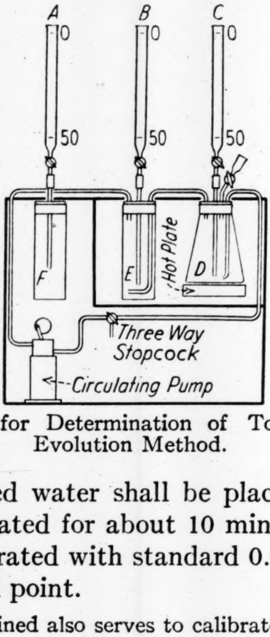

FIG. 1.—Apparatus Assembly for Determination of Total Carbon Dioxide by the Evolution Method.

NOTE.—The procedure outlined also serves to calibrate the apparatus against the air in the system.

(*d*) *Methyl Orange Indicator*.—Dissolve 1 g. of methyl orange in 1 liter of distilled water.

(*e*) *Phenolphthalein Indicator*.—Dissolve 5 g. of phenolphthalein in 1 liter of a 50 per cent solution of ethyl alcohol in distilled water.

Procedure

5. (*a*) A 50-ml. portion of 0.02 *N* barium hydroxide solution shall be measured into flask *E* from burette *A*, and flask *E* shall then be securely attached to the rubber stopper on burette *B*.

(*b*) A 200-ml. sample of the water to be tested, containing not more than 100 p.p.m. of total carbon dioxide, shall then be placed in flask *D*, methyl orange indicator added, and the flask attached securely to the rubber stopper of burette *C*. The hot plate shall be put into position under flask *D*. The three-way stopcock shall then be opened to the atmosphere and the circulating pump started. When bubbles appear in flask *D* the three-way stopcock shall be adjusted so that the gas circulates through the closed system comprised of flasks *D* and *E*.

(*c*) With the gas circulating (to stir the solution), 0.1 *N* H_2SO_4 from burette *C* shall be added to the sample in flask *D* to the methyl orange end point. The amount of acid used shall be recorded and then 20 ml. of acid added in excess.

(*d*) With the gas still circulating, the solution in flask *D* shall be heated until it just reaches the boiling point. The hot plate shall then be turned off.

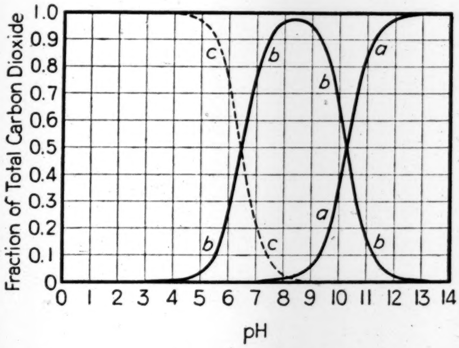

FIG. 2.—Curves Showing Fractions of Total Carbon Dioxide Present as the Respective Ions at Various Hydrogen Ion Concentrations.

(*e*) While constantly swirling the flask, the solution in flask *E* shall be titrated with 0.02 *N* HCl to the phenolphthalein end point.

Calculation

6. (*a*) The concentration of total carbon dioxide in parts per million of CO_2 shall be calculated as follows:

$$\text{Total } CO_2 = (A - B) \times 2.2 \times f$$

where A = the volume of 0.02 *N* acid equivalent to volume of 0.02 *N* $Ba(OH)_2$ used in standardization in milliliters,

B = the volume of 0.02 *N* acid used in analysis in milliliters, and

f = the correction factor for 0.02 *N* acid.

(*b*) The concentrations of carbonate and bicarbonate ions in parts per million of CO_3 shall be estimated by means of the curves shown in Fig. 2.[1]

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[1] D. S. McKinney, "Interpretation of Water Analysis," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 3, pp. 192 to 197 (1931).

To use these curves, which express the respective fractions of the total carbon dioxide present as undissociated carbonic acid, as bicarbonate ion, and as carbonate ion, the pH of the original sample must be known. From the determined value for pH, the value of the fraction of the total carbon dioxide present as carbonate ion, as bicarbonate ion, and as undissociated carbonic acid, shall be read respectively from curves *a*, *b* and *c* of Fig. 2. The concentrations of carbonate ion, bicarbonate ion, and undissociated carbonic acid in terms of parts per million, shall then be calculated as follows:

$$\begin{aligned} CO_3^{--} &= (A - B) \times 3 \times f \times a \\ HCO_3^{-} &= (A - B) \times 3.05 \times f \times b \\ H_2CO_3 &= (A - B) \times 3.1 \times f \times c \end{aligned}$$

where *a*, *b* and *c* = the fractions determined respectively from curves *a*, *b* and *c* of Fig. 2, and the other symbols have the meaning defined in Paragraph (*a*).

NOTE.—Since the preceding method of estimating ion concentrations is based upon data for the ionization of carbonic acid at 25 C., the values obtained hold for this temperature only. At any other temperature the ion concentrations will have other values, which may be calculated if the dissociation constants of carbonic acid at this temperature are known. The values for the ion concentrations obtained in this manner are first approximations based upon the assumption that the activity coefficient of each ion is unity.

TENTATIVE METHOD FOR DETERMINATION OF THE HYDROXIDE ION IN INDUSTRIAL WATERS[1]

A.S.T.M. Designation: D 514 – 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1938.

Scope

1. (*a*) There is no known method of chemical analysis by which the exact concentration of the hydroxide ion in water may be determined. Interpretation of any titration method is complicated by the fact that when salts such as carbonate, phosphate, aluminate, silicate or chromate, as well as some types of organic material, are present, they are titrated to a greater or less extent along with the hydroxide ion.

(*b*) This method covers the titration of water to which strontium chloride has been added to remove carbonate and phosphate ions. It is based upon the fact that since strontium carbonate and strontium phosphate are much less soluble than strontium sulfate, it is possible to free the solution of carbonate and phosphate ions without precipitating sulfate. This procedure minimizes turbidity and permits the direct titration of the hydroxide ion with decreased interference.

Application

2. This method is applicable in the examination of alkaline industrial waters such as boiler waters and boiler feedwaters under conditions where the water is practically free from organic matter, silicates and aluminates. If these are present in concentrations very low as compared with the concentration of the hydroxide ion the method may be used.

Special Solutions Required

3. (*a*) *Standard Acid* (*0.02 N*).—Prepare an 0.02 *N* solution of HCl or H_2SO_4 using reagent grade concentrated HCl (sp. gr. 1.19) or H_2SO_4 (sp. gr. 1.84), and standardize.

(*b*) *Strontium Chloride.*—Dissolve 4.5 g. of $SrCl_2 \cdot 6H_2O$, reagent grade, in 1 liter of distilled water.

(*c*) *Phenolphthalein Indicator.*—Dissolve 5 g. of phenolphthalein in 1 liter of a 50 per cent solution of ethyl alcohol in distilled water.

(*d*) *LaMotte Purple Indicator* (*1 per cent*).

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

Procedure

4. (*a*) A 100.0 ml. portion of the sample containing not more than 150 p.p.m. of hydroxide ion shall be measured into a 250-ml. Erlenmeyer flask. If the concentration of hydroxide is known to be higher than 150 p.p.m., a correspondingly smaller sample shall be used.

NOTE.—Thus, if the concentration of hydroxide ion were approximately 300 p.p.m., a 50-ml. sample shall be used.

(*b*) To the sample shall be added quickly 1.0 ml. of the strontium chloride solution for each 10 p.p.m. of carbonate ion present, 1.0 ml. for each 10 p.p.m. of orthophosphate ion present, and 4 ml. in excess.

NOTE.—If the magnitude of phosphate and carbonate concentrations in the sample is not known it will be necessary to add sufficient strontium chloride solution to precipitate what is thought to be the maximum concentrations of these ions that could exist in the water. The excess strontium chloride will produce no interference but may increase the turbidity of the sample by precipitation of strontium sulfate.

(*c*) A stopper shall be placed at once very lightly in the flask. The flask shall then be heated to boiling with the stopper in place but not allowed to boil for more than 2 or 3 sec. After standing hot for 2 or 3 min. the flask shall be cooled, under water if desired. The stopper shall remain in the flask at all times to prevent carbon dioxide from entering.

(*d*) If phosphate is *absent*, two or three drops of the phenolphthalein solution shall be added and the sample shall then be titrated with the 0.02 *N* acid until the phenolphthalein is colorless. The contents of the flask shall be swirled steadily during the addition of the acid to prevent redissolving of the precipitate.

(*e*) If phosphate is *present*, two or three drops of the LaMotte purple solution shall be added and the sample shall then be titrated to the end point of this indicator with the 0.02 *N* acid. A comparison blank should be used if the operator is not familiar with the end point of this indicator. The contents of the flask shall be swirled steadily during the titration.

NOTE.—The LaMotte purple indicator is recommended when phosphates are present, since in this case the phenolphthalein end point at a pH value of 8 fades rapidly due to the resolution of strontium phosphate. At the LaMotte purple end point above 9.3 this does not occur so readily. If LaMotte purple solution of the concentration employed as a pH indicator is used in place of the 1 per cent solution, 1 ml. will be required.

Calculation

5. The concentration of the hydroxide ion in terms of parts per million shall be calculated as follows:

$$\mathrm{OH}^- = \frac{340}{S} \times f \times V$$

where S = the volume of the sample in milliliters,
f = the acid correction factor, and
V = the volume of acid in milliliters used in the titration.

TENTATIVE METHOD FOR DETERMINATION OF THE TOTAL ORTHOPHOSPHATE AND CALCULATION OF THE RESPECTIVE ORTHOPHOSPHATE IONS IN INDUSTRIAL WATERS[1]

A.S.T.M. Designation: D 515 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

1. (*a*) Methods for orthophosphate determine the total of the orthophosphate ions, $H_2PO_4^-$, HPO_4^{--}, and PO_4^{---} as well as any undissociated H_3PO_4 present in a solution. It is possible, however, to calculate the concentrations of the various ions at room temperature from the value for total orthophosphate, provided the pH of the solution is known.

(*b*) This method covers two successive separations of the phosphate ion, as ammonium phosphomolybdate and as magnesium ammonium phosphate, respectively. The magnesium ammonium phosphate is ignited to magnesium pyrophosphate, and weighed.

Application

2. This method of analysis may be used for the analysis of any industrial water. When low concentrations of phosphate are encountered, however, large samples are required. If pyrophosphate or metaphosphate is present, it will be determined as orthophosphate by this method.

Special Solutions Required

3. (*a*) *Nitric Acid Reagent.*—Dissolve 500 g. of NH_4NO_3, reagent grade, in 350 ml. of distilled water and filter the solution. Add 350 ml. of concentrated HNO_3 (sp. gr. 1.42), reagent grade, to the filtrate, and dilute to 1 liter.

(*b*) *Ammonium Molybdate.*—Dissolve 75 g. of ammonium molybdate ($(NH_4)_6Mo_7O_{24} \cdot 4H_2O$), reagent grade, and 75 g. of NH_4NO_3, reagent grade, in 900 ml. of distilled water. Cool the solution, add 60 ml. of NH_4OH (sp. gr. 0.90), reagent grade, and dilute to 1 liter. Filter the solution before using.

(*c*) *Magnesia Mixture.*—Dissolve 55 g. of magnesium chloride ($MgCl_2 \cdot 6H_2O$), reagent grade, in a small amount of distilled water. Add to this solution, 280 g. of NH_4Cl, reagent grade, and 700 ml. of NH_4OH (sp. gr. 0.90), reagent grade, and dilute to 1 liter.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

(*d*) *Nitric Acid (sp. gr. 1.42).*—Concentrated HNO_3, reagent grade.

(*e*) *Hydrochloric Acid (sp. gr. 1.19).*—Concentrated HCl, reagent grade.

(*f*) *Ammonium Hydroxide (sp. gr. 0.90).*—Concentrated NH_4OH, reagent grade.

(*g*) *Diluted Ammonium Hydroxide (1:1).*—Prepare by diluting 500 ml. of NH_4OH (sp. gr. 0.90), reagent grade, to 1 liter with distilled water.

(*h*) *Diluted Ammonium Hydroxide (1:4).*—Prepare by diluting 200 ml. of NH_4OH (sp. gr. 0.90), reagent grade, to 1 liter with distilled water.

(*i*) *Nitric Acid Wash Solution.*—Dilute 10 ml. of HNO_3 (sp. gr. 1.42), reagent grade, to 1 liter with distilled water.

(*j*) *Ammonium Nitrate.*—Prepare a saturated solution of NH_4NO_3, reagent grade, in distilled water.

Procedure

4. (*a*) From a quantity of filtered sample, a volume containing from 0.004 to 0.04 g. of total P_2O_5 shall be measured into a beaker of suitable size. A 15-ml. portion of nitric acid reagent shall be added in excess of any amount necessary to neutralize the sample. The acidified sample shall then be heated to boiling and evaporated until the volume has been reduced to approximately 100 ml.

(*b*) *Precipitation as Ammonium Phosphomolybdate.*—The solution shall be cooled to about 80 C., 15 ml. of ammonium molybdate solution shall be added, and the solution shall be agitated until a cloudy precipitate appears. The precipitate shall be allowed to settle for 1 hr. on a steam bath at a temperature of 40 to 60 C., again agitated and then allowed to settle at room temperature for 1 hr. The precipitation may be hastened by adding potassium nitrate to the solution and bringing it almost to boiling. The precipitate shall be separated from the solution by filtration through a No. 42 Whatman filter paper, or equivalent. The filtrate shall be tested with additional ammonium molybdate solution for the presence of phosphate. The precipitate shall be washed five times with HNO_3 wash solution (1 per cent).

(*c*) *Reprecipitation as Magnesium Ammonium Phosphate.*—The precipitate shall be dissolved from the filter with a fine stream of hot NH_4OH solution (1:1), catching the solution in the beaker in which the precipitation was made. The volume of the combined solution and washings shall not exceed 100 to 150 ml. Hydrochloric acid shall be added to the solution until the yellow precipitate which appears dissolves with difficulty. To the cooled solution, 10 ml. of magnesia mixture shall be added one drop at a time with constant stirring. When the solution becomes cloudy, the stirring shall be discontinued, and the precipitate shall be allowed to settle for 10 min. Then, while the solution is being stirred, 25 ml. of concentrated NH_4OH (sp. gr. 0.90) for each 100 ml. of the original solution shall be added. The precipitate shall be allowed to settle for 2 hr. The precipitate shall be separated from the solution by filtration through an ignited and weighed Gooch crucible. The precipitate shall be washed with diluted NH_4OH (1:4) and a few drops of saturated NH_4NO_3 solution shall be placed in the crucible.

(*d*) *Ignition*.—The crucible shall be heated at a low temperature until the precipitate is decomposed and shall then be ignited at a red heat. The crucible and precipitate shall be cooled in a desiccator and weighed.

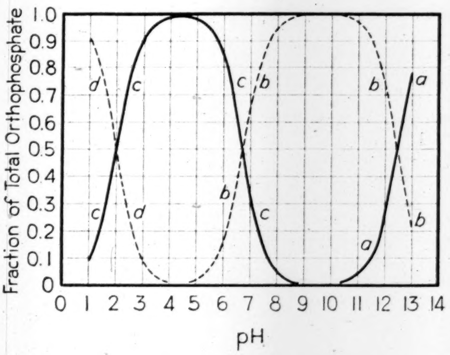

FIG. 1.—Curves Showing Fractions of the Total Orthophosphate Present as the Respective Orthophosphate Ions at Various Hydrogen Ion Concentrations.

Calculation

5. (*a*) The concentration of total orthophosphate in parts per million of P_2O_5 shall be calculated as follows:

$$\text{Total } P_2O_5 = \frac{W \times 637{,}900}{S}$$

where W = the weight of the crucible and precipitate minus the original weight of the crucible in grams, and

S = the volume of sample in milliliters.

(*b*) The concentrations of the respective orthophosphate ions in parts per million of PO_4^{---}, HPO_4^{--}, and $H_2PO_4^{-}$ shall be estimated by means of the curves in Fig. 1.[1] To use these curves, which express the respective fractions of the total orthophosphate present as undissociated orthophosphoric acid, and as the various ions, the pH of the original sample must be known. From the determined value for pH, the value of the fraction of the total orthophosphate present in each form shall be read from Fig. 1. The concentration of each ion and of the undissociated acid in parts per million shall then be calculated as follows:

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[1] D. S. McKinney, "Interpretation of Water Analysis," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 3, pp. 192 to 197 (1931).

$$PO_4^{---} = \frac{a \times W \times 853{,}400}{S}$$

$$HPO_4^{--} = \frac{b \times W \times 862{,}400}{S}$$

$$H_2PO_4^{-} = \frac{c \times W \times 871{,}500}{S}$$

$$H_3PO_4 = \frac{d \times W \times 880{,}600}{S}$$

where a, b, c and d = the values from the corresponding curves in Fig. 1.

NOTE.—Since the preceding method of calculating the concentration of the orthophosphate ions is based upon data for the ionization of orthophosphoric acid at 25 C., the values obtained hold for this temperature only. At any other temperature the concentrations of the respective ions will have some other value which may be calculated if the dissociation constants of orthophosphoric acid are known at this temperature. The values for the ion concentrations obtained in the manner described above are first approximations based upon the assumption that the activity coefficient of each ion is unity.

TENTATIVE METHOD FOR DETERMINATION OF THE SULFATE ION IN INDUSTRIAL WATERS[1]

A.S.T.M. Designation: D 516 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1938.

Scope

1. This method covers the precipitation and weighing of the sulfate ion as barium sulfate. While there is some tendency for other substances to be occluded or absorbed in the barium sulfate, usually there is no danger of serious interference. Where no ion other than sulfate is to be determined on the sample, removal of dissolved silica is unnecessary.

Application

2. This method may be used for the analysis of all industrial waters.

Special Solutions Required

3. (*a*) *Hydrochloric Acid* (*sp. gr. 1.19*).—Concentrated HCl, reagent grade.

(*b*) *Barium Chloride* (*10 per cent*).—Prepare a 10 per cent solution from $BaCl_2$, reagent grade, and distilled water.

(*c*) *Silver Nitrate - Nitric Acid Mixture.*—Prepare a solution containing 17 g. of $AgNO_3$, reagent grade, and 1 ml. of concentrated HNO_3 (sp. gr. 1.42), in 1 liter of distilled water.

Procedure

4. (*a*) A volume of clear sample containing sulfate equivalent to approximately 50 mg. of $BaSO_4$, as indicated by a preliminary qualitative test, shall be measured into a beaker, and shall be made faintly acid with HCl. If the solution is not clear, it shall be filtered through a 9-cm. filter paper, and the beaker and filter shall be thoroughly washed with hot distilled water.

(*b*) *Precipitation of Barium Sulfate.*—The clear, acidified solution shall be heated to boiling and to it shall be added dropwise slightly more than sufficient hot barium chloride solution (10 per cent) to precipitate all the sulfate. The mixture shall be kept hot until the liquid has become perfectly clear and the precipitate has settled out completely.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-19 on Water for Industrial Uses.

(*c*) *Filtration.*—While still hot, the solution shall be filtered through a No. 42 Whatman filter paper, or equivalent, and the precipitate shall be washed with hot distilled water until the washings are free from chlorides when tested with the silver nitrate - nitric acid mixture.

(*d*) *Ignition.*—The filter paper and contents shall be placed in a weighed crucible and the paper slowly charred and consumed without flaming. The residue shall be ignited for 1 hr. at approximately 800 C., cooled in a desiccator, and weighed.

Calculation

5. The concentration of sulfate ion in terms of parts per million shall be calculated as follows:

$$SO_4^{--} = W \times \frac{411,400}{S}$$

where S = the volume of sample in milliliters, and
W = the weight of $BaSO_4$ in grams.

Tentative Specifications for

SIEVES FOR TESTING PURPOSES[1]

(WIRE CLOTH SIEVES, ROUND-HOLE AND SQUARE-HOLE SCREENS OR SIEVES)

A.S.T.M. Designation: E 11 – 38 T

ISSUED AS TENTATIVE, 1925; ADOPTED, 1926; REVISED AND
REISSUED AS TENTATIVE, 1938.[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. These specifications cover woven-wire cloth sieves, round-hole screens (sieves) and square-hole perforated plate screens (sieves) for precision testing in the classification of materials according to size (mechanical analysis, fineness, and particle size determinations). The sieves covered by these specifications are intended for general use (Note 1). A method of calibrating woven wire cloth sieves is included as information in the Appendix.

NOTE 1.—Some industries may possibly require more restricted specifications for sieves for special testing purposes.

WOVEN WIRE CLOTH SIEVES

Sieve Cloth

2. (*a*) Wire cloth for standard sieves shall be woven (not twilled, except the cloth of the 62-, 53-, 44-, and 37-micron sieves) from brass, bronze, or other suitable wire, and shall not be coated or plated.

(*b*) The average opening between the adjacent warp and the adjacent shoot wires, taken separately, shall conform to that given in columns 2 and 3 of Table I, within the "permissible variation in average opening" given in column 4. The average diameter of the warp and of the shoot wires, taken separately, of the cloth of any given sieve shall be within the limits given in columns 6 and 7 of Table I. The maximum width of opening between adjacent warp or shoot wires shall not exceed the nominal width of opening by more than the "permissible variation in maximum opening" given in column 5 of Table I. An exception may be made, in the case of 8-in. sieves, if the total length of all the portions of rows of openings exceeding this maximum width is less than 4 in. in both the warp and the shoot directions, considered separately, and provided that the sieve is not rejected under Paragraph

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

These specifications are in effect a revision and consolidation of the former Standard Specifications for Sieves for Testing Purposes (E 11 – 26) and for Round-Hole Screens for Testing Purposes (E 17 – 36), which specifications were accordingly discontinued in 1938.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

(*d*). For sieves from the 1000-micron (No. 18) to the 37-micron (No. 400) size, inclusive, not more than 5 per cent of the openings shall exceed the nominal opening by more than one-half of the permissible variation in maximum opening.

(*c*) Both the warp and shoot wires shall be crimped in such a manner that they will be rigid when in use.

(*d*) There shall be no punctures or other obvious defects in the cloth.

NOTE 2.—The micron designation of the fine sieve series represents a strong trend among users of precision sieves toward the use of the micron terminology in reporting particle sizes. The openings of successive sieves of the fine series progress in the ratio $\sqrt[4]{2}:1$, and in selecting sieves from this series it is customary to take each sieve in a given range, every alternate sieve, or every fourth sieve.

Standard 8-in. Sieve Frames

3. (*a*) *Sieve Frames for Fine Series.*—Frames for all sieves of the fine series shall be the standard 8-in. size, except that frames 3 in. in diameter may be used in the case of sieves No. 100 and finer, used primarily in the testing of paint pigments. The standard frames shall be circular, 8 in. (20.32 cm.) in diameter. The height of the sieve from the top of the frame to the cloth shall be either about 2 in. (5 cm.), or 1 in. (2.5 cm.). Sieves having a height of 2 in. (5 cm.) shall be designated as full-height sieves; those having a height of 1 in. (2.5 cm.) as half-height sieves. The permissible variation on the mean inside diameter $\frac{3}{16}$ in. below the top of the sieve shall be plus $\frac{1}{32}$ in. The bottom of the sieve or "sieve skirt" shall be so constructed as to have an easy sliding fit in any sieve conforming to the above permissible variations and in no case shall this outside diameter be less than 7.970 in. nor more than 8.000 in. Pans and covers shall be so made as to be interchangeable with standard sieves.

(*b*) *Sieve Frames for Coarse Series.*—Sieves of the coarse series having nominal openings of less than 1 in. may have frames of the standard 8-in. size or may have larger frames as may be specified in individual cases. Frames for sieves of the coarse series having nominal openings of 1 in. or more may be made of either hardwood or metal and may be square, rectangular, or circular, as specified, a size larger than 8-in. being recommended. Frames, covers, and pans of the standard 8-in. size shall be made of brass, unless otherwise specified.

NOTE 3: *Special Sieves.*—These specifications do not preclude the use of special sieves for special purposes, as for example sieves having a diameter other than 8 in. or the nesting sieves for field use. When such sieves are used, in place of the standard 8-in. sieve, the cloth of the sieves should be required to conform to these specifications. The use of other than standard 8-in. sieves where these standard sieves could be used should be discouraged, as the results are not necessarily comparable.

(*c*) *Mounting of Cloth in Frame.*—The cloth shall be mounted on the frame without distortion, looseness, or waviness. To prevent the material being sieved from catching in the joint between the cloth and the frame, the joint shall be smoothly filled with solder or so made that the material will not catch.

Three-Inch Sieves

4. (*a*) Sieves 3 in. in diameter, used for testing paint pigments, shall be made from standard wire cloth No. 100 or finer. The sieve frames shall be circular, about 3 in. (7.6 cm.) in inside diameter, and shall not vary from this by more than plus or minus 0.16 in. (0.4 cm). The depth of the sieve from the top of the frame to the cloth shall not be less than 0.75 in. (1.9 cm.).

(*b*) The frames shall be constructed of first quality sheet brass in such a manner as to be permanently rigid. To prevent the material being sieved from

TABLE I.—NOMINAL DIMENSIONS, PERMISSIBLE VARIATIONS, AND LIMITS FOR WOVEN WIRE CLOTH OF STANDARD SIEVES.

Size in Inches or Sieve Designation	Sieve Opening		Permissible Variations in Average Opening, per cent	Permissible Variations in Maximum Opening,[a] per cent	Wire Diameter	
	Mm.	In.			Mm.	In.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			COARSE SERIES			
**	107.6	4.24	±2	+3	5.6 to 9.7	0.220 to 0.380
4-in.	101.6	4.00	±2	+3	5.6 to 9.7	0.220 to 0.380
3½-in.	88.9	3.50	±2	+3	5.3 to 9.3	0.210 to 0.365
3-in.	76.2	3.00	±2	+3	4.8 to 8.1	0.190 to 0.320
2½-in.	63.5	2.50	±2	+3	4.4 to 7.1	0.175 to 0.280
**	53.8	2.12	±2	+3	4.1 to 6.2	0.160 to 0.245
2-in.	50.8	2.00	±2	+3	4.1 to 6.2	0.160 to 0.245
1¾-in.	44.4	1.75	±2	+3	3.8 to 5.7	0.150 to 0.225
1½-in.	38.1	1.50	±2	+3	3.7 to 5.3	0.145 to 0.210
1¼-in.	31.7	1.25	±2	+3	3.5 to 4.8	0.140 to 0.190
**	26.9	1.06	±3	+5	3.43 to 4.50	0.135 to 0.177
1-in.	25.4	1.00	±3	+5	3.43 to 4.50	0.135 to 0.177
⅞-in.	22.2	0.875	±3	+5	3.23 to 4.22	0.127 to 0.166
¾-in.	19.1	0.750	±3	+5	3.10 to 3.91	0.122 to 0.154
⅝-in.	15.9	0.625	±3	+5	2.74 to 3.43	0.108 to 0.135
**	13.4	0.530	±3	+5	2.39 to 3.10	0.094 to 0.122
½-in.	12.7	0.500	±3	+5	2.39 to 3.10	0.094 to 0.122
7/16-in.	11.1	0.438	±3	+5	2.23 to 2.84	0.088 to 0.112
⅜-in.	9.52	0.375	±3	+5	2.11 to 2.59	0.083 to 0.102
5/16-in.	7.93	0.312	±3	+5	1.85 to 2.36	0.073 to 0.093
**	6.73	0.265	±3	+5	1.60 to 2.11	0.063 to 0.083
¼-in. (No. 3)	6.35	0.250	±3	+5	1.60 to 2.11	0.063 to 0.083
			FINE SERIES[b]			
5660 micron (No. 3½)	5.66	0.223	±3	10	1.28 to 1.90	0.050 to 0.075
4760 micron (No. 4)	4.76	0.187	±3	10	1.14 to 1.68	0.045 to 0.066
4000 micron (No. 5)	4.00	0.157	±3	10	1.00 to 1.47	0.039 to 0.055
3360 micron (No. 6)	3.36	0.132	±3	10	0.90 to 1.32	0.035 to 0.052
2830 micron (No. 7)	2.83	0.111	±3	10	0.80 to 1.20	0.031 to 0.047
2380 micron (No. 8)	2.38	0.0937	±3	10	0.74 to 1.10	0.0291 to 0.0433
2000 micron (No. 10)	2.00	0.0787	±3	10	0.68 to 1.00	0.0268 to 0.0394
1680 micron (No. 12)	1.68	0.0661	±3	10	0.62 to 0.90	0.0244 to 0.0354
1410 micron (No. 14)	1.41	0.0555	±3	10	0.56 to 0.80	0.0220 to 0.0315
1190 micron (No. 16)	1.19	0.0469	±3	10	0.50 to 0.70	0.0197 to 0.0276
1000 micron (No. 18)	1.00	0.0394	±5	10[a]	0.43 to 0.62	0.0169 to 0.0244
840 micron (No. 20)	0.84	0.0331	±5	10[a]	0.38 to 0.55	0.0150 to 0.0217
710 micron (No. 25)	0.71	0.0280	±5	10[a]	0.33 to 0.48	0.0130 to 0.0189
590 micron (No. 30)	0.59	0.0232	±5	10[a]	0.29 to 0.42	0.0114 to 0.0165
500 micron (No. 35)	0.50	0.0197	±5	10[a]	0.26 to 0.37	0.0102 to 0.0146
420 micron (No. 40)	0.42	0.0165	±5	25[a]	0.230 to 0.330	0.0091 to 0.0130
350 micron (No. 45)	0.35	0.0138	±5	25[a]	0.200 to 0.290	0.0079 to 0.0114
297 micron (No. 50)	0.297	0.0117	±5	25[a]	0.170 to 0.253	0.0067 to 0.0100
250 micron (No. 60)	0.250	0.0098	±5	25[a]	0.149 to 0.220	0.0059 to 0.0087
210 micron (No. 70)	0.210	0.0083	±5	25[a]	0.138 to 0.187	0.0051 to 0.0074
177 micron (No. 80)	0.177	0.0070	±6	40[a]	0.114 to 0.154	0.0043 to 0.0061
149 micron (No. 100)	0.149	0.0059	±6	40[a]	0.096 to 0.125	0.0036 to 0.0049
125 micron (No. 120)	0.125	0.0049	±6	40[a]	0.079 to 0.103	0.0030 to 0.0041
105 micron (No. 140)	0.105	0.0041	±6	40[a]	0.064 to 0.087	0.0025 to 0.0035
88 micron (No. 170)	0.088	0.0035	±6	40[a]	0.054 to 0.073	0.0021 to 0.0030
74 micron (No. 200)	0.074	0.0029	±7	60[a]	0.045 to 0.061	0.0018 to 0.0025
62 micron (No. 230)	0.062	0.0024	±7	90[a]	0.039 to 0.052	0.0015 to 0.0022
53 micron (No. 270)	0.053	0.0021	±7	90[a]	0.035 to 0.046	0.0014 to 0.0019
44 micron (No. 325)	0.044	0.0017	±7	90[a]	0.031 to 0.040	0.0012 to 0.0017
37 micron (No. 400)	0.037	0.0015	±7	90[a]	0.023 to 0.035	0.0009 to 0.0014

** The five sieves marked in the first column with a double asterisk (**) may be used instead of the 4-in., 2-in., 1-in., ½-in., and ¼-in. sieves when it is desired to have a series of sieves nesting with the Fine Series and continuing that series with the $\sqrt[4]{2}:1$ ratio. All of the other sieves listed above are in a $\sqrt[4]{2}:1$ ratio with the Fine Series within the limit of the specified permissible variations. Care should be taken in designating the five sieves marked with the double asterisk; they should not be designated as 4-in., 2-in., 1-in., ½-in., and ¼-in., but as 4.24-in., 2.12-in., 1.06-in., 0.530-in., and 0.265-in. (or by the manufacturer's nominal values, for example, 1.050-in., 0.525-in., and 0.263-in).

[a] For sieves from the 1000-micron (No. 18) to the 37-micron (No. 400) size, inclusive, not more than 5 per cent of the openings shall exceed the nominal opening by more than one-half of the permissible variation in maximum opening.

[b] **See Note 2, Section 2.**

catching in the joint between the cloth and the frame, the joint shall be smoothly filled with solder or so made that the material will not catch.

Label Marking

5. Each sieve (except the 3-in. sieve) shall bear a label with the following information: the designation of the sieve (the nominal size of the opening in inches for the coarse series, and the micron designation or the U. S. Standard Sieve Series Number for the fine series), the name of the Series (for example, "U. S. Standard Sieve Series," or a specific manufacturer's series), the name of the manufacturer or responsible distributor, and the opening in inches and millimeters.

Calibration of Sieves and Sieve Cloth

6. The first test of any sieve should be to determine whether it conforms to the specifications. If a suitable standard of powdered or granular material is available for a fineness test, that test is advisable as an additional means of calibration. Pieces of unmounted sieve cloth should be tested in sections of a size suitable for mounting in the sieve frames. In some cases it may be desirable to make a detailed systematic microscopic test of the sieve, plotting the frequency of occurrence of different sizes of openings across the sieve, rejecting, if necessary, a sieve found to have an excessive nonuniformity of sizes of openings for the particular purpose for which the sieve is to be used. Details of methods of calibration are given in the Appendix.

Presentation of Data

7. Sieve tests shall be presented in tabular or graphical form in terms of the nominal sieve opening and the percentage by weight. For purposes of comparison the cumulative percentage undersize will be accepted as standard. This does not preclude the representation of percentages on individual sieves providing the sieve interval is clearly specified as plus one sieve number and minus another, or as between two sieve apertures. Graphical representation may include the use of logarithmic scales, probability paper, etc., to emphasize specific characteristics of shape.

ROUND-HOLE SCREENS (SIEVES)

Plates

8. Plates used in the manufacture of round-hole screens shall be made of brass, bronze, steel, or other rigid metal. Thickness of plates shall be governed by size of openings as well as screening area of screens and shall conform to the following requirements:

Screening Area, sq. in.	Diameter of Opening, in.	Thickness of Plate, in.	
		Minimum	Maximum
Under 100	All sizes............	0.049	0.066
100 and over	1/16 and 1/8...........	0.049	0.066
	1/4 to 2 1/2, incl.......	0.060	0.100
	3 and 3 1/2...........	0.075	0.130
	4 and 5.............	0.105	0.160
	6 and 8.............	0.120	0.175

Type of Frame

9. Frames for laboratory screens shall be at least 8 in. in diameter. Frames for standard 8-in. laboratory screens shall conform to the requirements specified in Section 3 for woven wire-cloth sieves. Frames for large screens may be made of either hardwood or metal and may be square, rectangular, or circular, as specified. For screens having circular openings 1 in. in diameter or larger, frames larger than 8 in. in diameter are recommended.

Spacing of Openings

10. (*a*) Spacing of openings shall conform to the following requirements:

Nominal Diameter of Opening, in.	Nominal Width of Metal Between Adjacent Openings, in.
$\frac{1}{16}$	$\frac{3}{64}$
$\frac{1}{8}$	$\frac{3}{32}$
$\frac{1}{4}$	$\frac{1}{8}$
$\frac{3}{8}$	$\frac{3}{16}$
$\frac{1}{2}$	$\frac{3}{16}$
$\frac{5}{8}$	$\frac{3}{16}$
$\frac{3}{4}$	$\frac{1}{4}$
$\frac{7}{8}$	$\frac{1}{4}$
1	$\frac{3}{8}$
$1\frac{1}{4}$	$\frac{3}{8}$
$1\frac{1}{2}$	$\frac{1}{2}$
2	$\frac{5}{8}$
$2\frac{1}{2}$	$\frac{3}{4}$
3	$\frac{3}{4}$
$3\frac{1}{2}$	$\frac{3}{4}$
4	$\frac{3}{4}$
5	1
6	1
8	1

(*b*) The openings shall be so arranged that their centers lie at the vertices of triangles which are approximately equilateral within the limits given by the permissible variations in width of metal and diameter of opening.

Permissible Variations for Openings and Spacings

11. (*a*) For screens having openings $\frac{1}{4}$ in. or less in diameter, the actual diameter of any opening shall not vary from the nominal diameter more than plus or minus 5 per cent.

(*b*) For screens having openings over $\frac{1}{4}$ in. in diameter, the actual diameter of any opening shall not vary from the nominal diameter more than plus or minus 3 per cent.

(*c*) The width of metal between the adjacent openings in the screen plate shall not vary from the nominal value given in Section 10 (*a*) more than plus or minus 20 per cent.

Calibration

12. The diameters of the openings of the screens shall be measured by means of an accurate steel rule or by other suitable means. The use of "paddle gages" (flat plug gages) or of tapered pin gages is recommended for checking these openings more precisely.

Presentation of Data

13. The presentation of data for round-hole screens shall follow the same general procedure as that specified in Section 7 for square apertures, but in all cases the term *diameter* shall be applied to the size of the opening.

Square-Hole Perforated Plate Screens (Sieves)

Square-Hole Screens

14. Where square-hole perforated plate screens are specified for use, the openings shall be the same as the openings of woven wire cloth sieves, but in other respects they shall conform to the requirements for round-hole screens specified in Sections 8 to 13.

APPENDIX

Method of Calibrating Woven Wire Cloth Sieves

A1. To determine whether a sieve conforms to the foregoing specifications, the apparatus used may be of the general type as the following which was described in the National Bureau of Standards *Circular Letter 72*, July 26, 1922, and the test method may follow the procedure herein described:

The apparatus consists of a light-tight box about 40 cm. square and 1 meter in length, with a microscope mounted on one end and a ground glass plate 2 mm. in thickness in the other end. The source of illumination is a microscope illuminator containing a concentrated filament lamp, 6 v., 108 watts, connected through a transformer to a 110-v. alternating current supply circuit. The light passes through a lens in the end of the illuminator and is focused on the objective of the microscope. After passing through the microscope it diverges to the ground glass plate which is mounted with the ground side in. A 50-cm. steel scale is mounted against the inner face of the ground glass screen in such a way that the graduations of the scale may be seen through the glass. The position of the scale allows a direct reading on the edges of the image cast by the wire of the sieve and avoids parallax due to the thickness of the glass. It was found that by oiling the ground surface slightly, the visibility was greatly increased without diminishing the distinctness of the image.

A frame for holding the sieve is placed on a platform so arranged as to permit a lateral motion of about 8 in., and also motion at right angles for focusing. Long rods, extending to the end of the apparatus at which the observer is seated, enable the observer to move the sieve without leaving his place, the lateral motion being accomplished by means of a rack and pinion and the focusing by the use of beveled gears. If the frame were also provided with a vertical motion, the utility of the apparatus would be increased. A green glass filter is placed between the lamp and the condensing lens. The filter relieves eye strain very considerably and practically eliminates the color bands otherwise appearing on the edges of the image.

In use, the sieve is mounted in its holder on the focusing platform, between the illuminator and the objective of the microscope, and is focused by the observer until a sharp image is seen on the ground glass. Measurements are then taken in millimeters by reading the positions on the steel scale where the two edges of the image of the wire cross it, a reading glass being sometimes used. The sieve is then moved across the field, readings being taken at several places on the cloth, until the whole diameter of the sieve has been covered, care being taken at the same time to watch for the uniformity of spacing and to measure any excessively large openings. The sieve is then rotated through 90 deg. and the process repeated.

The magnification of the apparatus may be determined by means of a calibrated stage micrometer.

By using a microscope having a tube about 15 cm. long and an eyepiece with a magnifying power of approximately eight diameters, together with a 16-cm. objective, a magnification of about 250 diameters is obtained.

The National Bureau of Standards has found by experience that in testing sieves for conformity to standard specifications, the most reliable results are obtained by measuring the wire diameters and determining the number of wires per centimeter, and then computing the average opening. From five to ten wires, sometimes more, are measured depending upon the uniformity of diameter of the wire, the closeness of the measurements of the cloth to the limits permitted by the permissible variations, and the experience of the observer. Four measurements are made on each wire. Large openings are measured at the same time.

Magnifications found suitable and convenient at the National Bureau of Standards are:

SIEVES	MAGNIFICATIONS
590 micron (No. 30) and coarser..........	45
500 to 250 micron (Nos. 35 to 60), incl....	90
210 to 37 micron (Nos. 70 to 400), incl....	250

Greater magnifications would be feasible if the distance from the microscope to the screen were increased, provided the optical parts of the microscope were of sufficient quality.

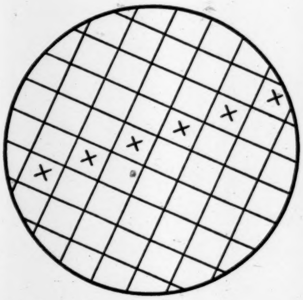
In making all measurements, the readings of the steel scale are given by estimating to 0.1 mm.

The most generally used method of determining the *mesh* of the sieve is by means of what is sometimes known as "picket-fence interference," also the "moire effect." For the No. 200 sieve, a glass scale is accurately graduated with 200 lines to the inch, the opaque lines being about equal in width to the space between the lines. The exact number of lines per unit length is immaterial, however, provided the graduation is uniform and the exact number per unit length is known. When a scale such as this is laid on a piece of woven wire cloth having a mesh per unit length somewhat approximating the number of lines per unit length, and a strong light is placed beneath, a number of dark bands will appear which in a unit length are equal in number to the difference between the mesh of the cloth and the graduation of the scale. If the scale is moved lengthwise, in a direction perpendicular to the lines, the dark bands will also move. If these bands move in the same direction as the motion of the scale, the mesh of the sieve is less, if the motion is in the opposite direction, the mesh is greater than the number of lines on the scale. If some bands move in one direction and some in the other, the number moving in each direction must be counted separately, and the algebraic sum taken as the number of bands. For sieves 840 micron (No. 20) to 210 micron (No. 70), inclusive, the best results are obtained with a transparent line about the width of a wire diameter ruled on an opaque background. For sieves coarser than these it is usually necessary to count the fringes by the aid of a hand lens using a steel scale as the standard. Scales should be calibrated before being used in testing sieves.

The limiting values for average opening and for maximum opening are found by multiplying the nominal values by the percentage permissible variations,—considered as exact figures followed by zeros after the decimal point,—and rounding off the result to the same number of decimal places as given in columns 2 or 3 of Table I.

A2. If it is desired to plot the frequency of occurrence of different sizes of openings across the sieve, 100 openings in the sieve should be measured in a diagonal direction across the sieve, then 100 openings are measured in a diagonal direction at right angles to the first. Six fields are chosen in each direction, and in any one field the diagonal method of measurement is used as illustrated in the accompanying diagram.

Each opening is measured between the warp wires and also between the shoot wires; the warp readings and the shoot readings are separately tabulated and plotted.



Only the indicated openings are measured.

A3. The National Bureau of Standards accepts sieves for test to determine conformity to specifications.

A4. Glass scales such as are described above may be obtained from: Bausch & Lomb Optical Co., Rochester, N. Y., and Keuffel & Esser Co., Hoboken, N. J.

TENTATIVE GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS[1]

A.S.T.M. Designation: E 19 - 38 T

ISSUED, 1938.[2]

This **Tentative Standard** of the American Society for Testing Materials is, under its Regulation, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. The chart consists of a series of grain outlines representing the grain sizes which may be encountered in the austenite of various steels, at different temperatures in the austenite range.

Establishing Austenite Grain Size

2. As may be agreed upon between the manufacturer and the purchaser, austenite grain size (see Notes 1 and 2) shall in this standard be established either:

(*a*) by carburizing at 1700 F. (925 C.) for 8 hr. (the McQuaid-Ehn test), which is recommended for carburizing grades, or

(*b*) by heating at a temperature not over 50 F. (28 C.) above the normal heat-treating temperature and for not over 50 per cent more than the normal heat-treating time, the normal values being those mutually agreed upon.

The rate of cooling depends on the method of treatment, as will be evident from the methods described in Section 3

NOTE 1.—Numerous methods are in use for establishing austenite grain size, and a knowledge of grain-coarsening behaviors is helpful in deciding which method to use. The size of austenite grains, in any particular steel, depends primarily on the temperature to which that steel is heated and the time it is held at the temperature. It should be remembered that the atmosphere in heating may affect the grain-growth behavior at the outside of the piece.

NOTE 2.—Austenite grain size is influenced by most previous treatments to which steel may have been subjected, as, for example, quenching, normalizing, hot working, and cold working. It is therefore advisable, when testing for austenite grain size, to consider the effects of prior or subsequent treatments on the precise piece (or typical piece) which is under consideration.

Revealing the Grain Size

3. For revealing austenite grain size the following methods are generally used:

(*a*) by outlining the grains with cementite, as in carburizing (McQuaid-Ehn test) or as in high-carbon steels, or

(*b*) by outlining the grains with ferrite, as in the hypoeutectoid zone in carburizing, or in medium-carbon steels generally, or by an interrupted cooling on low-carbon steels, or

(*c*) by fine pearlite outlining martensite grains, as in eutectoid steels at a not quite fully hardened zone, or

(*d*) by appropriate etching of fully hardened martensite, or

(*e*) by an oxidation method.

Measuring the Grain Size

4. The measurement of grain size shall be carried out by comparing the microscopic image at 100 diameters magnification with the standard grain size chart in Plate I. Absolute grain sizes may be calculated from Table I, which shows the

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[1] Under the standardization procedure of the Society, this chart is under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

This chart is in effect a tentative revision of the Standard Grain Size Chart for Classification of Steels (E 19 - 33), 1936 Book of A.S.T.M. Standards, Part I, p. 761.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 25, 1938.

PLATE I
PROCEEDINGS, AM. SOC. TESTING MATS.
VOL. 38, PART I

TENTATIVE GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

A.S.T.M. DESIGNATION: E 19 - 38 T

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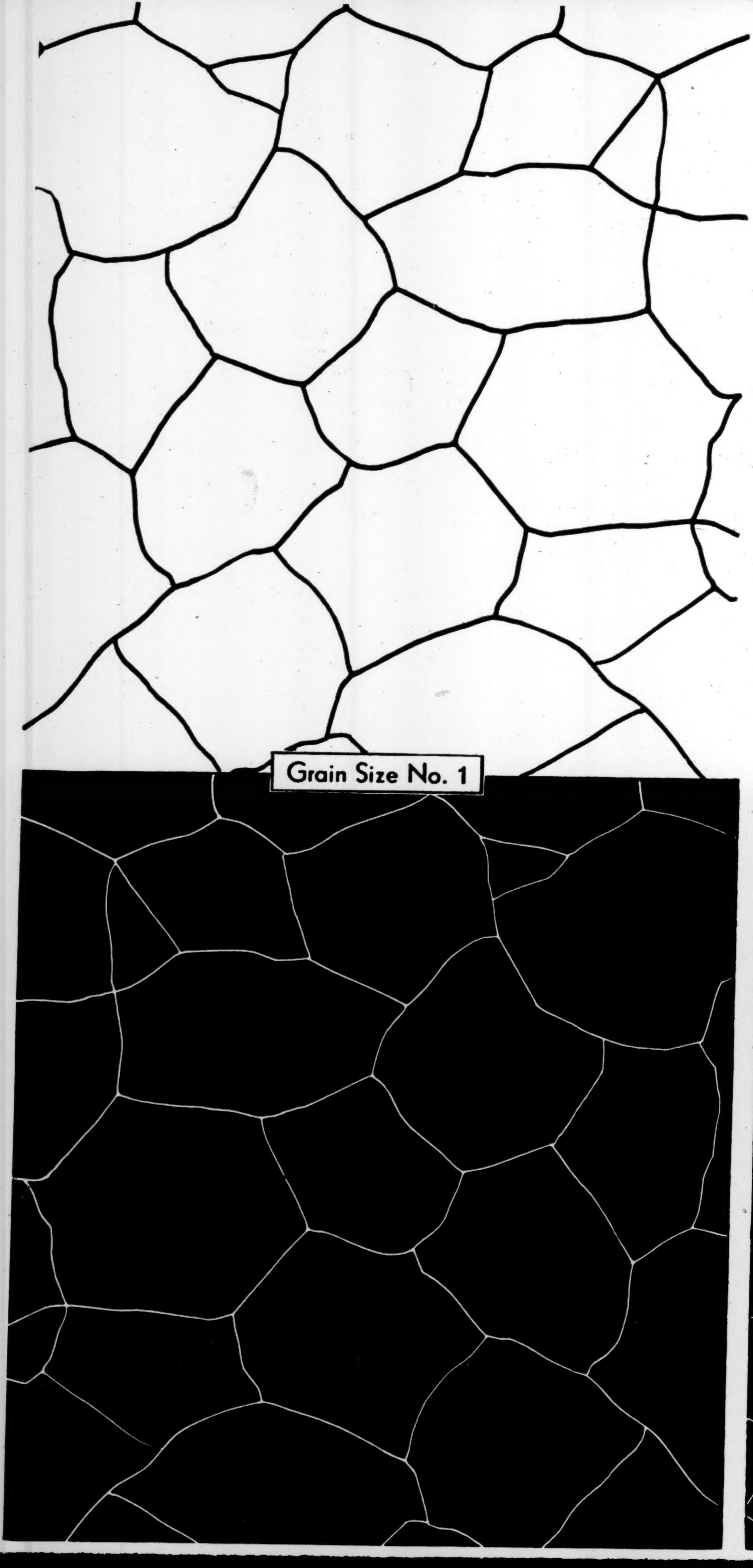
260 S. BROAD ST., PHILADELPHIA, PA.



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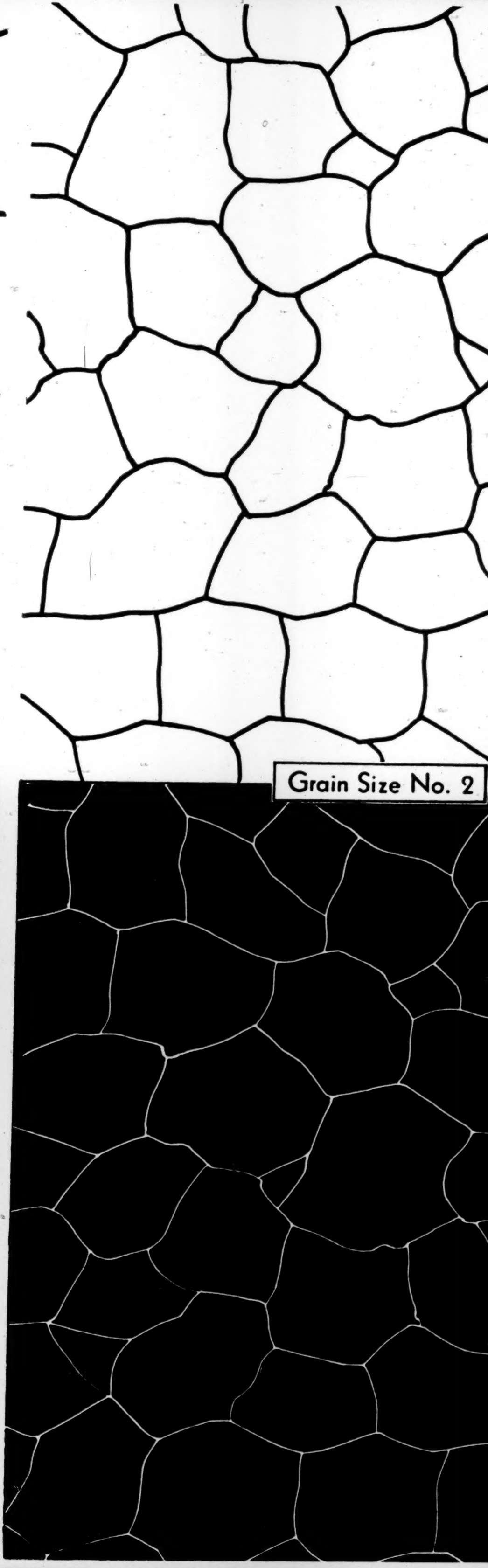

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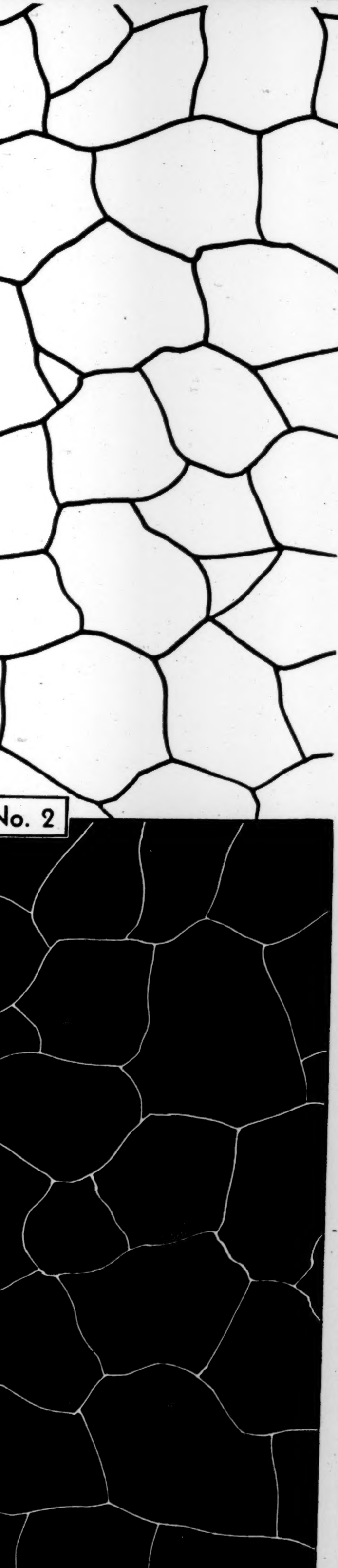
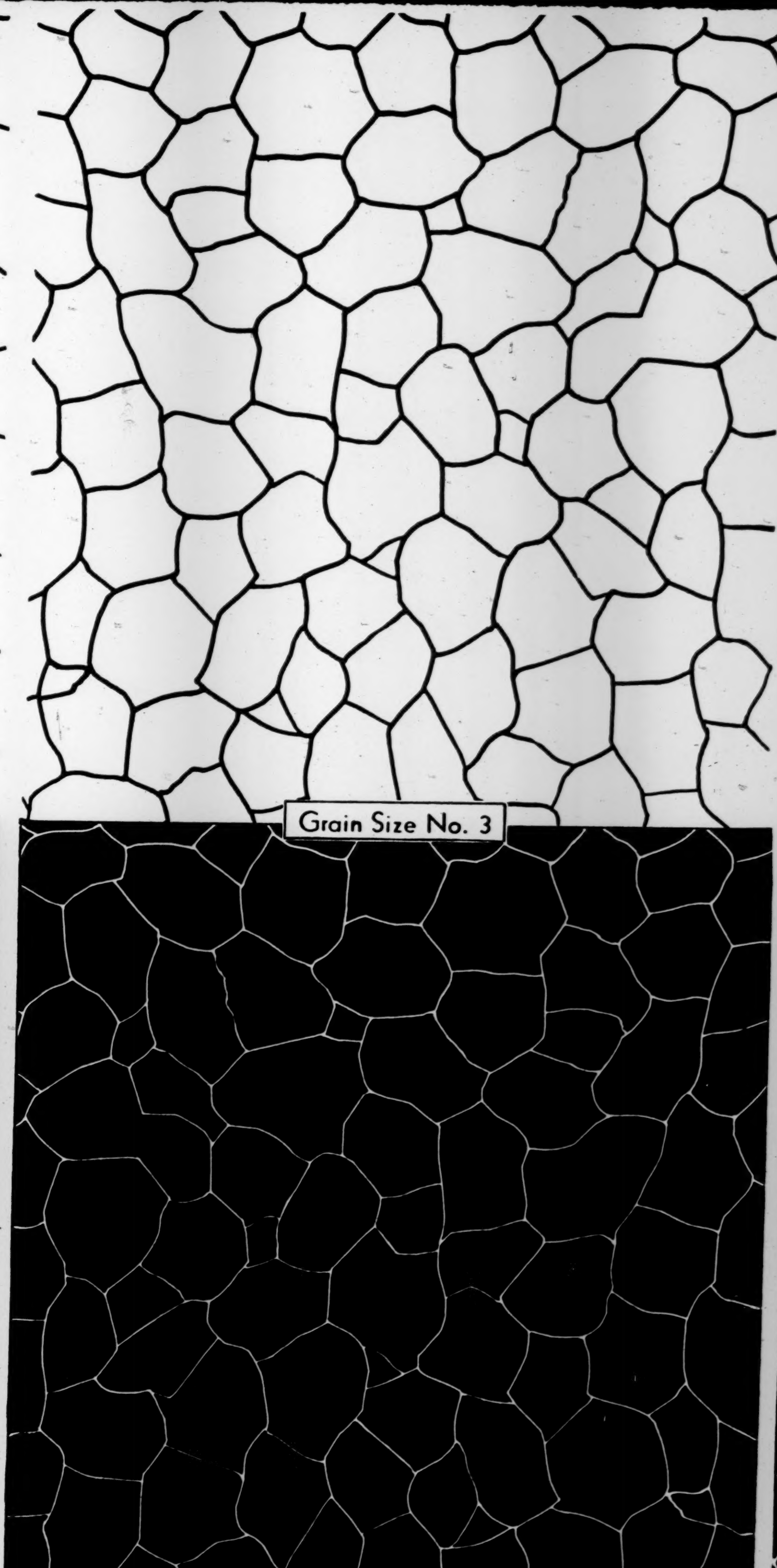
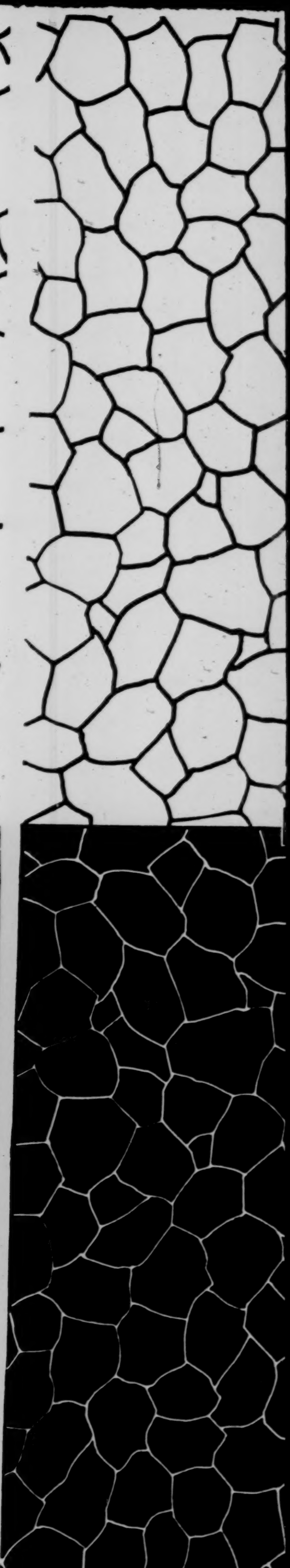
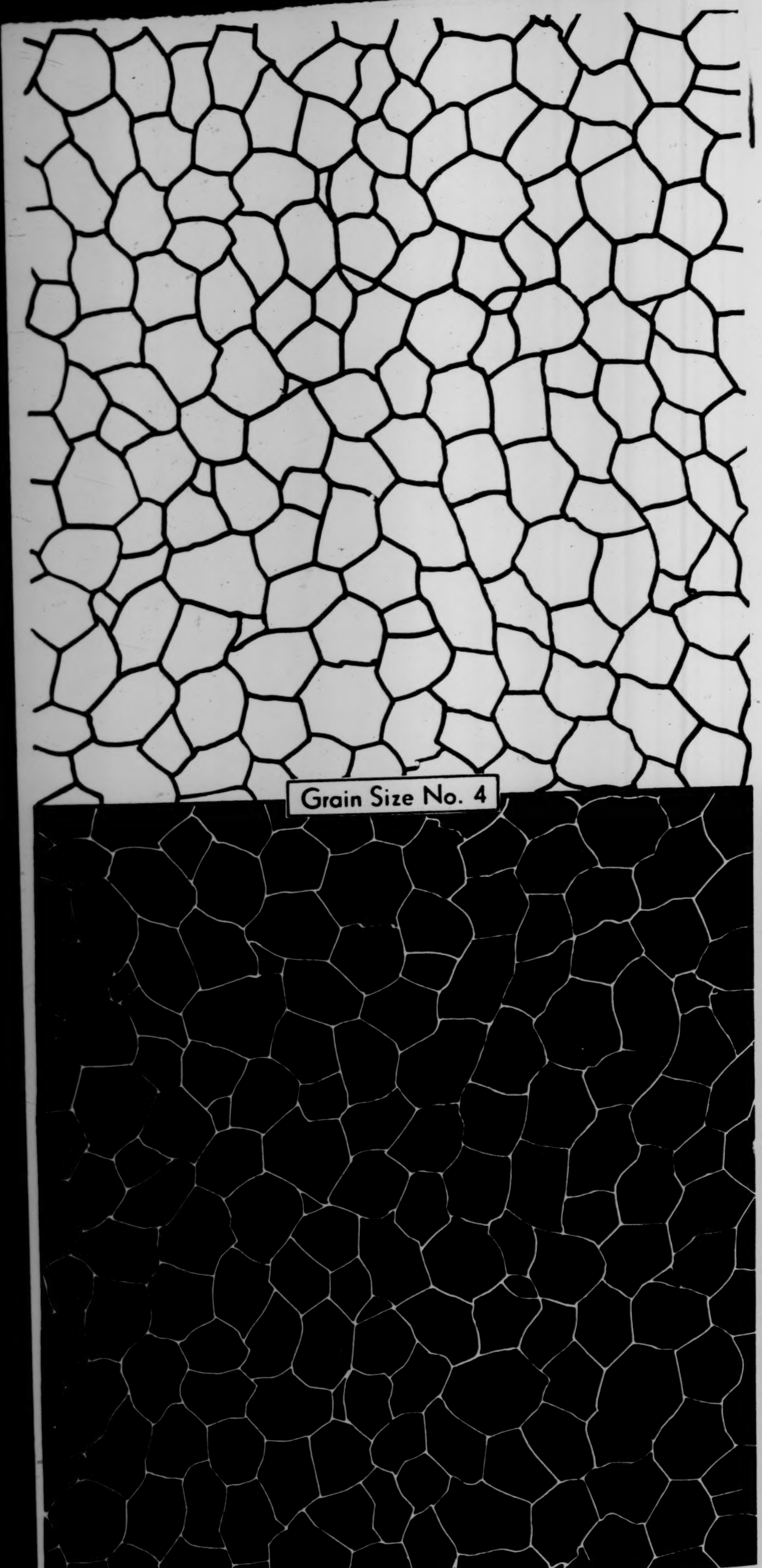


No. 2



Grain Size No. 3

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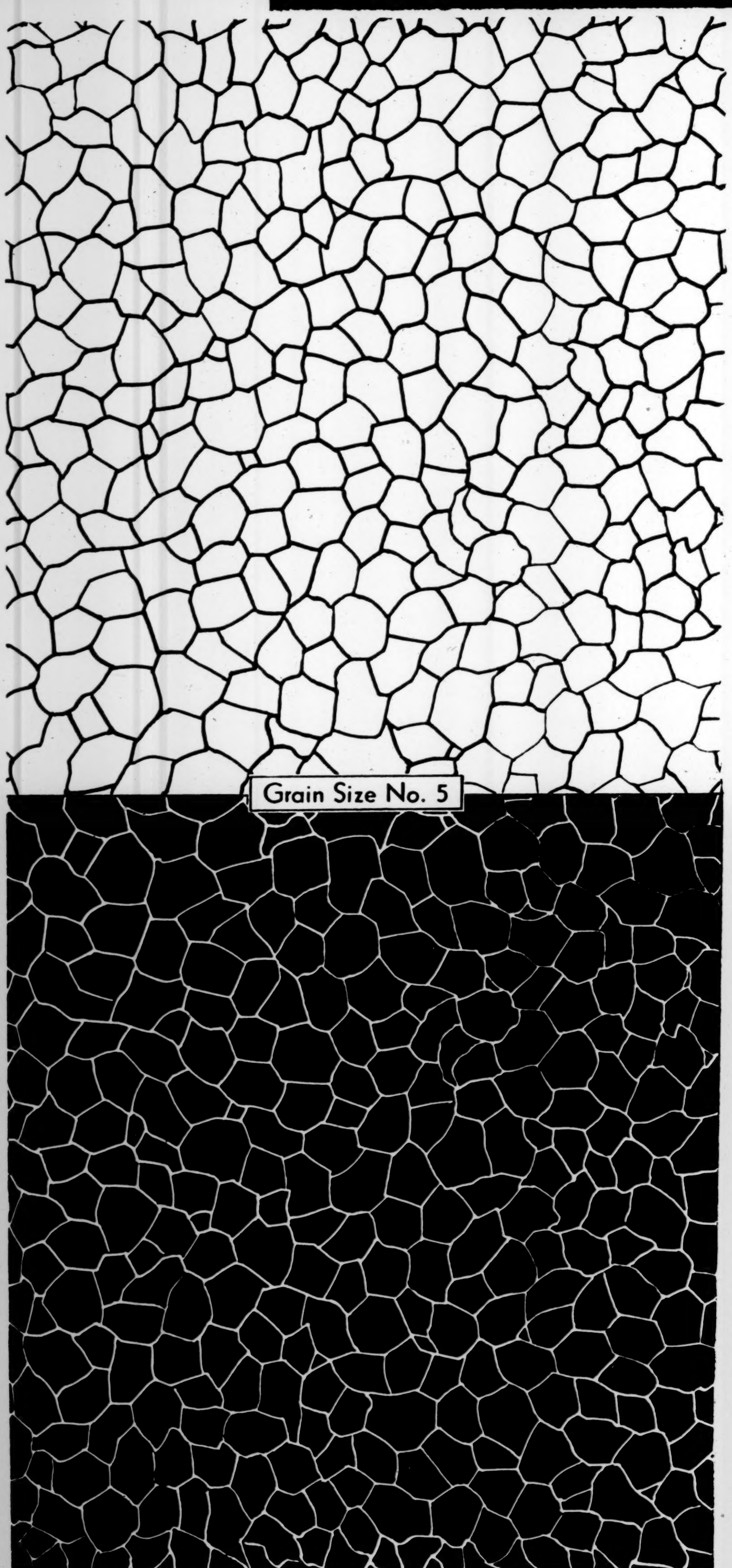
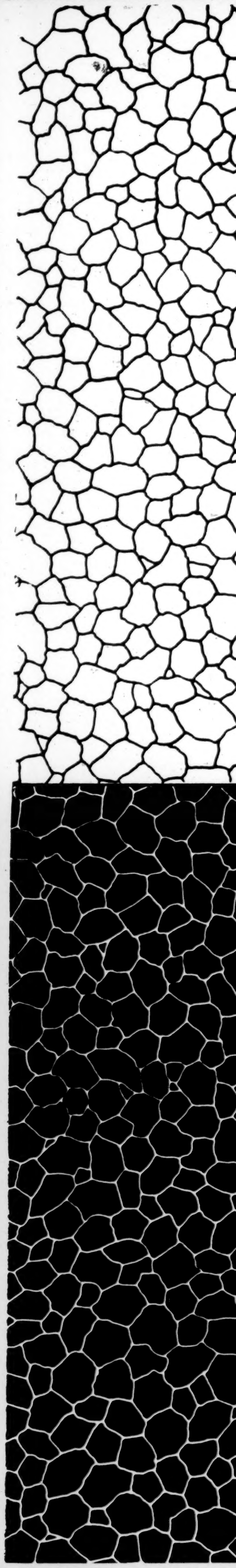
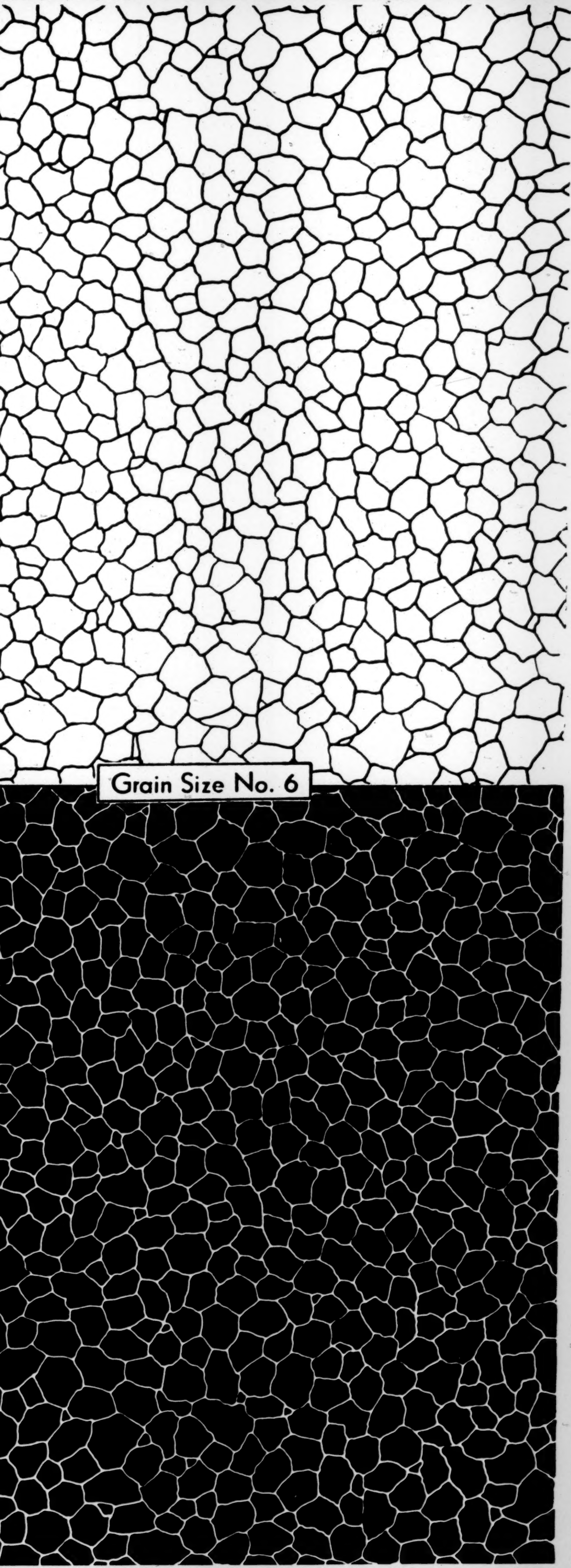
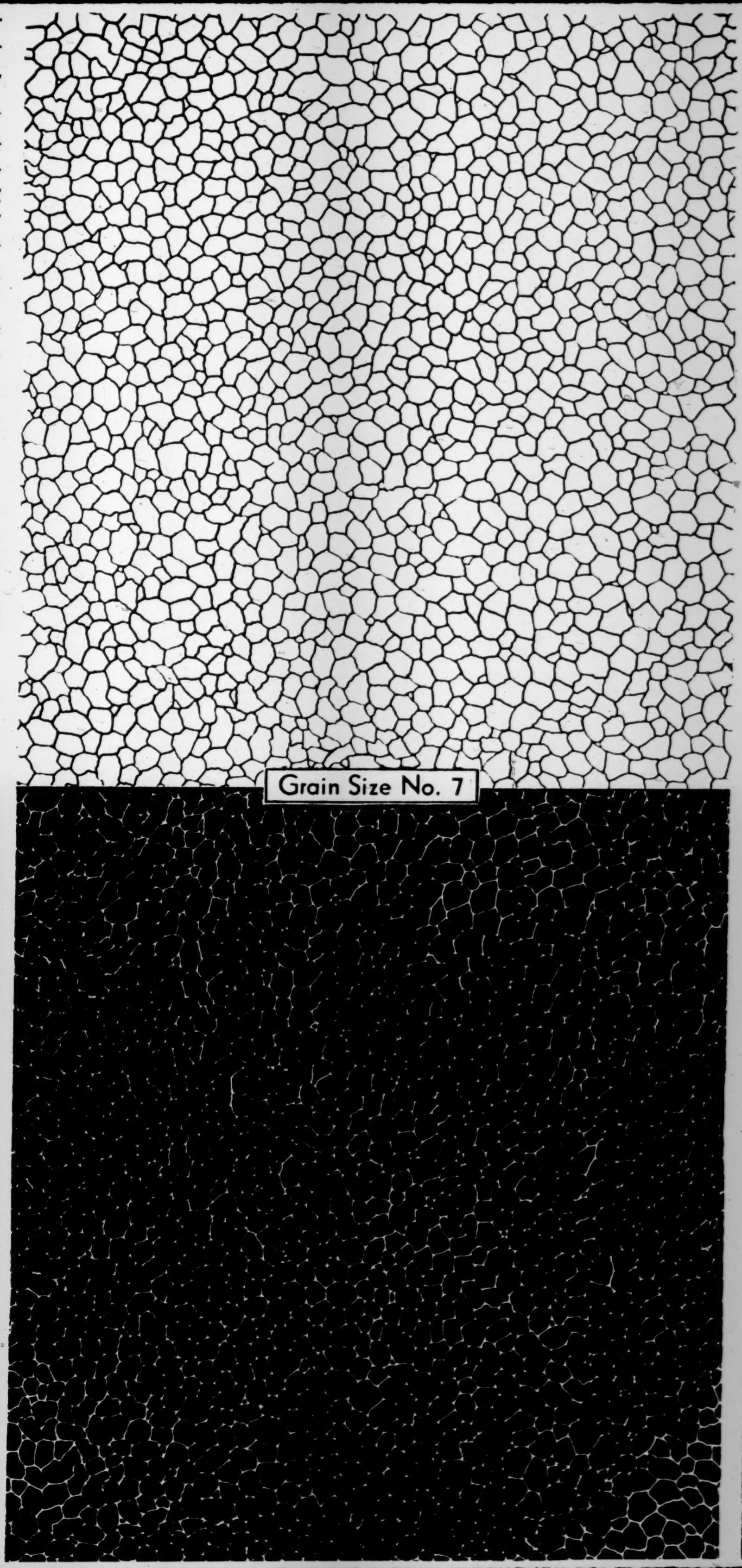

Grain Size No. 5





Grain Size No. 6



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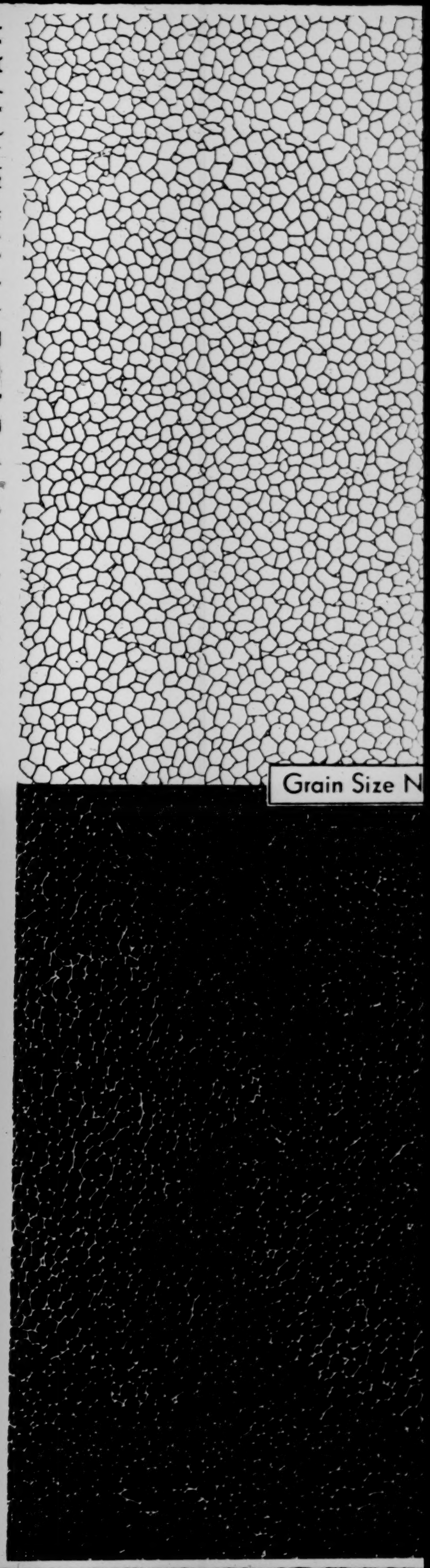
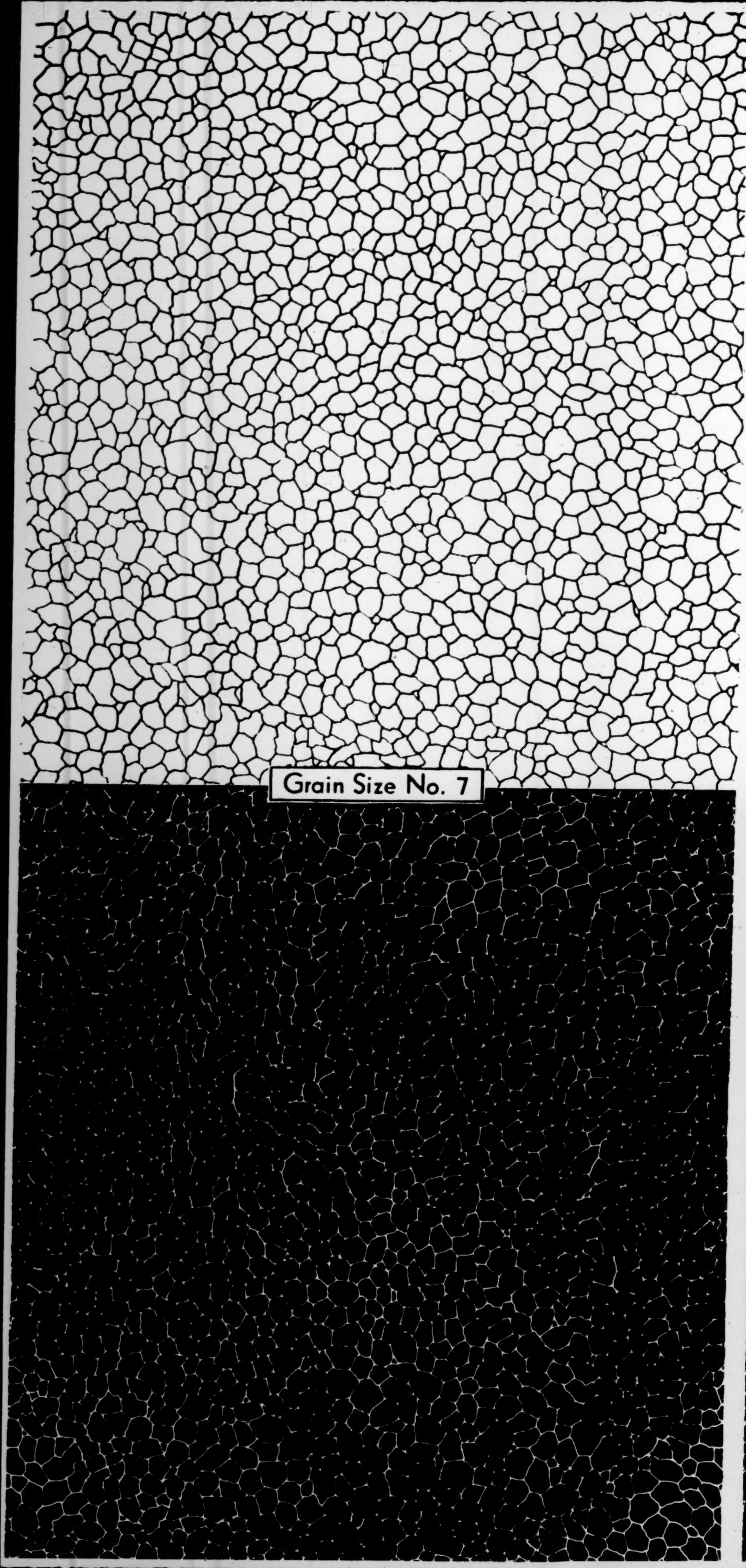
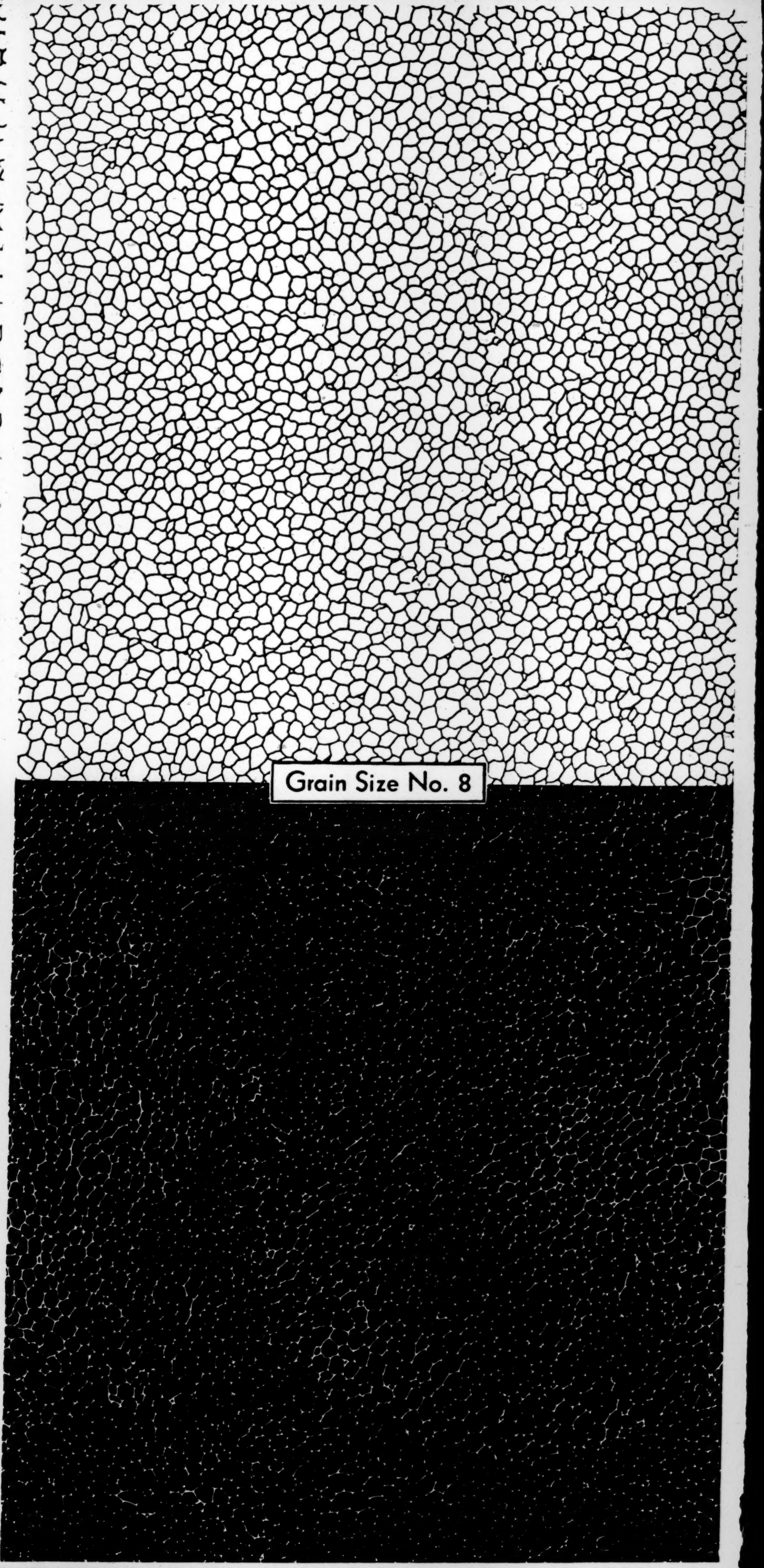


Grain Size N



Grain Size No. 7



Grain Size No. 8

sizes as they appear in the chart and also the actual grain sizes.

TABLE I.—GRAIN SIZE RELATIONSHIPS, ACTUAL AND AS OBSERVED AT 100 DIAMETERS MAGNIFICATION.

A.S.T.M. Grain-Size Number[a]	Mean Number of Grains per Square Inch as Viewed at 100 Diameters	Calculated Diameter of Equivalent Spherical Grain (not magnified)		Calculated Mean Area of Cross-Section of Grain (not magnified), sq. in.
		in.	mm.	
No. 1.......	1	0.0113	0.287	0.000 1
No. 2.......	2	0.00800	0.203	0.000 05
No. 3.......	4	0.00567	0.144	0.000 025
No. 4.......	8	0.00400	0.101	0.000 012 5
No. 5.......	16	0.00283	0.0718	0.000 006 25
No. 6.......	32	0.00200	0.0507	0.000 003 13
No. 7.......	64	0.00142	0.0359	0.000 001 56
No. 8.......	128	0.00100	0.0254	0.000 000 78

[a] With the present state of the art of steel-making, the commercial size ranges Nos. 1 to 4, and Nos. 5 to 8 suggest coarse and fine ranges, respectively.

NOTE.—Larger sizes Nos. 00 and 0 may be read by using a magnification of 50 diameters (instead of 100) and using grain sizes Nos. 1 and 2 on the chart, respectively. Smaller grain sizes Nos. 9 and 10 may be read by using a magnification of 200 diameters (instead of 100) and using grain sizes Nos. 7 and 8 on the chart, respectively.

Report

5. In reporting grain size, the test conditions should be stated, including the temperature and time used in establishing the austenite grain size, and the method of revealing the grain size.

Fracture Method

6. There are in use today sets of fracture standards, in which the grain size is judged from the appearance of the fracture. It has been found that the arbitrarily numbered fracture grain sizes agree very well with the arbitrarily numbered grain sizes presented in Plate I. This coincidence makes the fracture grain sizes interchangeable with the austenite grain sizes determined microscopically (except that "duplexing" or mixed grain size is not readily discernible in fractures). The sizes observed microscopically shall be considered the primary standard, since they can be determined with measuring instruments.

TENTATIVE METHOD OF BEND TESTING FOR DUCTILITY OF METALS[1]

A.S.T.M. Designation: E 16 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1931, REVISED, 1938.[2]

Scope

1. This method of bend testing consists essentially of bending the specimen by means of forces at the ends and without introducing additional forces at the point of maximum bending. This is followed by measurements of the elongation of the outside fibers at the point of maximum bending. This is known as free bending with measurement of the fiber elongation.

NOTE.—Although most of the work with this test has been carried out on rolled iron and steel, sufficient work has been done with other forms of ferrous material, as well as with hardened copper alloys and other non-ferrous metals, to show that the principles involved are applicable, although it will be necessary to work out the details in each case. It is obvious that if the specimen bends flat upon itself without fracture no quantitative data in addition to this fact may be obtained. Work on producing failure in such highly ductile materials by special means is under way, and recommendations may be made at a subsequent date. It is equally obvious that if the material is so brittle as to preclude an initial end bend, the test is not applicable. However, there is little need for a bend test if such a condition exists.

TEST SPECIMEN

Preparation of Test Specimens

2. (*a*) For results in which the measured performance is independent of the thickness of the specimen, rectangular specimens with widths at least one and one-half times the thickness shall be used. The edges shall be smoothed so that the fracture will not take place at the edge. A radius up to one-eighth the thickness of the specimen may be used on the edges. The outside surfaces of the specimen shall be smooth and free from local defects and transverse scratches. The length may vary with the thickness of the piece and is unimportant provided it is long enough to perform the bending operation.

(*b*) Round bars may be tested by this method but the results will only be comparative, as for the same material the fiber elongation is found to vary slightly with the diameter.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

[2] Revision accepted by Committee E-10 on Standards, August 25, 1938.

Gage Length

(*c*) The gage length in which the elongation is measured shall be 0.3 in. in the case of plate from $\frac{1}{4}$ to $\frac{1}{2}$ in. in thickness and 1 in. for all plates over $\frac{1}{2}$ in. in thickness. This gage length shall be located at the section of maximum bending and in the center third of the width of the specimen.

NOTE.—Experiments have shown that the gage length is not critical, so that the apparent discontinuity at $\frac{1}{2}$ in. does not lead to errors in excess of the allowable. For certain special applications such as welds it may be desirable to use other gage lengths. In such cases, the gage length used shall be at least equal to the thickness of the plate and not more than twice the thickness of the plate but shall in no case be more than 1 in.

PROCEDURE

Method of Starting the Bend

3. When starting the bend any local stress or strain at the section which eventually will have the greatest bending should be avoided. This may be accomplished by holding the specimen in a vise about one-third from the end, producing an initial bend at this point by hammer blows, or the specimen may be set up on cross supports and the initial bend started by compression at the third points. The initial bend shall be far enough from the final point of maximum bending so as not to affect it. This shall be performed on both ends of the specimen. The initial bend may vary from 5 to 30 deg., depending on the ductility of the material. The magnitude of this initial bend does not affect the results.

Method of Closing the Bend

4. (*a*) The specimen with initial bends on each end shall be placed in a vise or press as a strut and compression applied at the ends. The vise or press shall be closed until failure of the outside fibers occurs. The speed is not a factor provided actual shock is avoided. The continuity of closing and the speed may be varied at will without affecting the results beyond the duplicability specified in Section 6.

(*b*) Bending may be carried out in special machines by any other suitable means provided that local stresses at the point of maximum bending are avoided. If such stresses are not avoided low values will result.

Measurement of Fiber Elongation

5. (*a*) The performance of the specimen in the bend test shall be evaluated by the measurement of the outside fiber elongation. The most direct method of performing this is to measure with a flex-

ible scale the final length between gage marks placed on the specimen before bending, allowance being made for the width of any cracks included in the final gage length.

(*b*) Any other method of measuring the fiber elongation which gives the same values as the direct method described in Paragraph (*a*) may be used. For example, in some cases it may be objectionable to put gage marks on the specimen. In this event the radius of the outside of the specimen may be measured and the elongation calculated. For simplified operation a bend extensometer has been developed, which reads fiber elongation directly when placed on the curved surface. Any such method is satisfactory if, as above stated, the values obtained are consistent with the method of direct measurement.

NOTE.—With material less than ¼ in. in thickness the difficulties in measurement of elongation are so great that the committee is not yet prepared to make any recommendations. The committee is continuing the study of this problem and hopes to make recommendations at a future date.

Duplicability

6. The duplicability of the test results as obtained by this procedure when applied to rolled steel plate will be within 15 per cent of the fiber elongation. The duplicability of the test when applied to other materials will vary, as the nature of the material will affect the accuracy of the end point determination.

TENTATIVE METHOD OF TEST
FOR
LONG-TIME (CREEP) HIGH-TEMPERATURE TENSION TESTS OF METALLIC MATERIALS[1]

A.S.T.M. Designation: E 22 - 38 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1937, 1938.

Scope

1. (*a*) This method covers the determination of the amount of extension of metallic materials due to the combined effects of temperature, tensile stress, and time.

NOTE.—Since the characteristics which render a material resistant to extension under the condition of test are not yet completely known, the details of the procedure considered herein are those known to have important influences. Since others equally important may in the future be discovered, the recommended details of the method are largely advisory in nature.

(*b*) Test periods depend upon the reasonable life expected from the material in service. Test periods of less than 1 per cent of the expected life are not deemed to give significant results. Tests extending to 10 per cent of the expected life are preferable where feasible. The uncertainties of extrapolation should be considered in deciding upon the length of the test.

Possibilities and Limitations

2. (*a*) Inherently the creep test is a long-time test and not convenient for acceptance purposes. Its primary use is in the evaluation of materials.

(*b*) Creep is an extremely sensitive index of strength, plastic extension usually varying as some power of the stress from 1 to 20 depending upon the material, stress, temperature, and time.

(*c*) A comparatively simple creep test may suffice to indicate the order of strength of a material and show if it is very good or very bad. However, short-time and long-time tests may indicate different relative merits of material.

(*d*) In the application of the following test requirements and recommendations it is assumed that test specimens of a given material are essentially comparable and truly representative of the material. In tests conducted to show the effects of temperature or stress as variables, great care must be used to insure that the specimens are representative of the material and essentially identical. Departure from this assumption may introduce discrepancies as great as, if not greater than, those due to departure from details of procedure outlined in this method of test.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the Joint A.S.M.E.-A.S.T.M. Research Committee on Effect of Temperature on the Properties of Metals.

Fundamental Measurements

3. The measurements to be recorded include: Extension, length, time, load, cross-sectional area, and temperature. Of these six quantities, length, time and cross-sectional area present little difficulty, while frictional effects are the only particular considerations in connection with the applied load. Measurement of extension and temperature are more difficult.

Test Specimens

4. Test specimens should be of uniform cross-section to within plus or minus 0.5 per cent throughout the gage length. For round specimens, diameters of 0.505 in., 0.357 in., or 0.252 in., and a gage length of not less than 2 in., are recommended. Longer gage lengths and the 0.505-in. diameter are preferred. The surface should be machined smooth and free from tool marks and scratches.

Loading

5. (*a*) The applied load should be accurately measured to within 1 per cent. Direct dead-weight loading or the use of a simple lever is preferred.

(*b*) Great care should be taken to avoid eccentricity. With short gage lengths and heavy shackles, readings should be taken on opposite sides of the specimen, unless the entire assembly of specimen and pull rods has been checked for alignment in a suitable fixture prior to the test. A long rod facilitates obtaining proper alignment.

Temperature Measurement

6. (*a*) The determination of the temperature of the specimen during test is the most important single measurement in connection with creep testing, because small variations in temperature may produce large changes in creep rate.

(*b*) Care must be taken to insure accurate temperature measurement over the gage length of the specimen throughout the test.

(*c*) Reliable temperature measurements should be made at sufficiently frequent intervals to insure an accurate determination of the average test temperature and compliance with Section 8 (*c*). At the conclusion of the test there should be at least 50 such observations of temperature, the average of which should be reported as the actual test temperature.

Temperature Control

7. For tests at a particular temperature, the furnace should be maintained at constant temperature, preferably by a suitable automatic control device.

Temperature Variation

8. (*a*) While maintenance of uniform temperature over the gage length of the specimen and throughout the duration of the test are required, it is recognized that small fluctuations are necessary for effective control.

(*b*) For specimens having a gage length of less than 5 in., the maximum variation of temperature over the gage length should not exceed ± 3 deg. Fahr. from the average test temperature for temperatures up to and including 1200 F., ± 5 deg. Fahr. from the average test temperature for temperatures up to and including 1600 F., and ± 10 deg. Fahr. for temperatures over 1600 F. For all longer gage lengths, the maximum variation of temperature should be kept as small as possible. For all gage lengths the extent of the variation in temperature must be stated in reporting each test.

(*c*) The maximum fluctuation of temperature throughout the duration of the test period should be kept as small as possible. The extent of this fluctuation should be stated in reporting the tests. The breadth of the normal control cycle should be made a matter of record for the apparatus.

Extension Measurement

9. (*a*) The accuracy of extension-measuring equipment should be suitable for the purposes for which the materials under test are likely to be applied and should be made a part of the report as prescribed in Appendix II.

(*b*) Throughout the duration of a test observation of extension should be made at sufficiently frequent intervals to define the extension-time curve.

(*c*) Where total extensions are limited to the same order of magnitude as elastic extensions, it is important to have the elastic portion of the total extension accurately known.

NOTE.—This may be accomplished by application of the load in steps and the plotting of an extension-load line. The slope of such a line gives the value of the elastic modulus at the temperature of the test and any departure from proportionality in the direction of excess extension should be taken as observed plastic extension. The careful setting of a microscope and subsequent reading of a micrometer are not conducive to rapid readings such as facilitate accurate measurement of the elastic fraction of extension. Since the early stages of creep occur many times as fast as the later stages, excessive slowness in obtaining measurements of elastic extension usually leads to an excessive value of the "initial" extension and deficient creep results. Under these circumstances, if the elastic extension is not determined and noted to be consistent with an acceptable value of the modulus of elasticity, a deficient measurement may result. This condition may be rectified at the termination of the test by measuring the immediate elastic contraction on removal of the load while the test temperature is maintained.

Conditions of Test

10. The method of test outlined envisages the measurement of extension during the application of pure tensile stress at high temperature. They are equally applicable whether the stress or the extension is maintained at a constant value for the duration of the test.

Plotting of Results

11. (*a*) Extension-time curves should be plotted on ordinary rectangular coordinate paper at amply large scale and such curves should state

whether or not elastic extension is included and, if so, what it is. Time is preferably expressed in hours.

(*b*) For a particular temperature, log-log plots of stress *versus* rate of creep are desirable. Such plots are useful within the limits of determined values.

(*c*) For each material a semi-log plot of (log) strength *versus* temperature is desirable. For the higher temperatures, such plots approach straight lines.

Form for Reporting Results

12. (*a*) It is recommended that essential information for identification of the material tested be collected on the Form shown in Appendix I.

NOTE.—While it is recognized that this Form is still incomplete it is included herewith as Appendix I with the understanding it will be subject to revision as additional knowledge accumulates as to other essential characteristics. In this Form, Table IV on Creep Characteristics, is intended to take the place of plotted results for the purpose of printed reproduction only.

(*b*) A tabular arrangement, intended to reflect the essential qualities of the testing equipment as briefly as possible, is included as Appendix II.

Precautions Necessary in Applying Results

13. (*a*) Engineers are particularly cautioned against assuming that the same rates of creep occur under conditions of compound stress such as characterize shells, pipes, beams, or wheels as occur during a pure tension test. Examples of pure tensile stress steadily maintained at high temperature are probably not common. The centrifugal pull at the root of a turbine bucket running at constant speed and with but little steam bending stress is an example. On the other hand, every bolt is an example of pure tensile stress in which the extension is maintained, the initial elastic extension being replaced by the plastic extension of creep with a corresponding decrease in stress. Both types of test are used for comparison of the relative creep resistance of materials.

(*b*) For comparative purposes a nominal strength may be determined by plotting on log-log paper applied stresses and corresponding rates either at the end of a specified test period or at a specified total extension.

(*c*) Nominal strengths determined at constant stress may be used to determine allowable steady tensile stresses by suitable analytic extrapolation. Nominal strengths determined at constant extension may be used to determine allowable bolt stress, and initial upsets by suitable analytic interpretation. Such procedures are beyond the scope of a test method, but engineers are cautioned that the nominal strengths determined in accordance with the suggested procedure should not be used in the same manner as working stresses at ordinary temperatures, because the conditions of service, the behavior of the material, and the circumstances surrounding failure or misfunctioning are totally different.

APPENDIX I

FORM FOR REPORTING DATA AND RESULTS OF LONG-TIME (CREEP) HIGH-TEMPERATURE TENSION TESTS.[1]

LABORATORY DESIGNATION:

MATERIAL:

I. DESCRIPTION OF MATERIAL

Type Wrought:
Cast: Separately:
Integrally:

Form of Material
Bars:
Tubes:
Plates:
Forgings:
Keel Blocks:
Castings:
Longitudinal
Transverse:

Dimensions

Heat Treatment — **1st** **2nd** **3rd** **4th**
Type:
Temperature:
Holding Time:
Size of Material Treated:

Chemical Composition:

C Mn P S Si Ni Cr W V Mo Cu Al Others

Initial Micro-Structure:

X100

Austenitic Grain Size Established: A.S.T.M. No.
(a) by carburizing test (McQuaid-Ehn) ....
(State whether case or core.)
(b) at final heat-treating temperature above critical range. (State method used to reveal austenitic grain size) ....

Normality:

Hardness:
Brinell:
Rockwell B:
Rockwell C:
Others:

Grain Size in Specimen as Tested ....
(State constituent rated.)

Impact
Izod:
Charpy:
Specimen Dimensions:

Initial Physical Properties (all stresses in pounds per square inch)

Temperature, deg. Fahr.	Tensile Strength	Yield Point	Yield Stress 0.2% Set	Proportional Limit	Elongation in 2 in., %	Reduction of Area, %	Impact, ft-lb.		Modulus of Elasticity	Poisson's Ratio	Lateral Plastic Contraction
							Charpy	Izod			

II. MANUFACTURING DATA

Type Furnace
Acid or Basic:
Electric Arc:
Induction:
Open Hearth:

Size Melt:
Size Ingot:
Size Billet:
Size Finished Product:

Deoxidation:
Straightening:
Treatment:

III. ROOM TEMPERATURE PROPERTIES OF SPECIMENS AFTER CREEP TESTS

Creep Testing			Tensile Strength	Yield Point	Prop. Limit	Elongation in 2 in., %	Reduction of Area, %	Impact, ft-lb.		Hardness
Temperature, °F	Stress	Time, hr.						Charpy	Izod	

Microstructures of Completed Creep Specimens

Temp.: Time: Stress:

Temp.: Time: Stress:

Temp.: Time: Stress:

Temp.: Time: Stress:

IV. CREEP CHARACTERISTICS

Testing Temperature, °F	Stress, Lb./Sq. In.	Total Time, Hr	Total Creep, In./In.	Average for Past Interval	Tangent to Curve	Intercept, In./In.	Stress for Designated Creep Rate		
				Millionth In./In./Hr					

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[1] Copies of the above form, 11 x 20 in. in size, printed on durable transparent paper suitable for blueprinting are available as follows: single copy, 25 cents; pad of 25, $1.00.

APPENDIX II

CHARACTERISTICS OF TEST EQUIPMENT

NOTE.—Exact figures are not necessary but unless it is possible to furnish information which is approximately correct, the item should be left blank.

1. Gage length, in

2. Specimen diameter, in

3. Estimated friction, per cent

4. Maximum temperature variation, deg. Fahr
(Over gage length, one normal condition: hottest point minus coldest point.)

5. Maximum temperature fluctuation, deg. Fahr
(During control cycle, one normal condition: hottest instant minus coldest instant.)

6. Number of temperature readings
(Average of each specimen survey constitutes one reading.)

7. Number of standard temperature checks
(How often is furnace temperature checked by independent standard temperature indicator.)

8. Temperature of reference rod
(Answer "test" for gage rod inside furnace, or "room" for microscope standard outside.)

9. Expansion ratio of gage rod to specimen
(For gage rod in furnace the ratio of the coefficients of thermal expansion of gage rod to specimen.)

9*a*. Are extension readings corrected?
(Yes or no. (If ratio is near 1.0, no correction necessary.))

10. Thermal expansion of microscope standard
(For microscope standard outside; coefficient or thermal expansion per degree Fahrenheit of microscope standard.)

10*a*. Maximum room temperature variation, deg. Fahr
(Hottest room temperature while reading minus coldest room temperature while reading.)

10*b*. Are extension readings corrected?
(Yes or no. (For fluctuation of temperature of specimen (item 5) and of standard (item 10*a*).) For small fluctuations and low thermal expansion, no correction necessary.)

11. Number of extension readings

12. Smallest scale division, in. per in
(Reading, one full divsion, inches per inch of gage length.)

13. Smallest scale division, in
(Actual size.)

14. Magnification ratio
(13 to 12.)

15. Usual reading, fraction
($\frac{1}{10}$, $\frac{1}{5}$ or $\frac{1}{2}$ of smallest scale division.)

16. Usual reading, in. per inch of gage length

17. Gage setting, automatic or manual
(If dial or mirror is operated by gage rod answer "automatic." If operator sets microscope answer "manual.")

17*a*. Width of cross hair, in. per inch of gage length

17*b*. Width of gage mark, in. per inch of gage length

18. Thermal capacity of furnace, kwh

19. Radiation rate, kw

20. Maximum power input, kw

21. Minimum power input, kw

TENTATIVE REVISIONS
OF
A.S.T.M. STANDARDS

Tentative revisions of A.S.T.M. Standards are printed for one or more years with a view of eliciting criticisms, of which the committee concerned will take due cognizance before recommending final action.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Revisions to the Headquarters of the Society, 260 So. Broad St., Philadelphia, Pa.

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS

Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts and Other Forgings for Locomotives and Cars (A 63 - 36):[1]

The Tentative Specifications for Normalized Quenched-and-Tempered Alloy-Steel Forgings (A 63 – 38 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications A 63 – 36.

Tentative revision, submitted June, 1938.

Standard Specifications for Electric-Fusion-Welded Steel Pipe (Sizes 30 in. and Over) (A 134 - 36):[1]

Section 1.—Change this section to read as follows by the addition of the italicized words:

> 1. These specifications cover steel pipe 30 in. in diameter and over, with a wall thickness up to $\frac{3}{4}$ in., inclusive, manufactured by the *straight seam or spiral seam* electric-fusion-welding process.

Tentative revision, submitted August, 1938.

Section 4.—Change this section to read as follows by the addition of the italicized word:

> 4. If required by the purchaser, the test specimen taken *perpendicularly* across the weld shall show a tensile strength not less than the minimum tensile strength specified for the plate.

Tentative revision, submitted August, 1938.

Section 5.—Change the first sentence of this section to read as follows by the addition of the italicized word:

> If required by the purchaser, the test specimen taken *perpendicularly* across the weld shall stand being bent cold through 180 deg. around a pin the diameter of which is equal to $4\frac{1}{2}$ times the thickness of the plate, without developing cracks.

Tentative revision, submitted August, 1938.

Section 7 (a).—Change the first sentence of this section to read as follows by the addition of the italicized word and the omission of the words in brackets:

> If required by the purchaser, test specimens shall be taken *perpendicularly* across the weld and from the end of the pipe or at any point in the pipe required by the inspector and shall be cut [perpendicularly to the axis of the pipe] with the weld approximately in the middle of the specimen.

Tentative revision, submitted August, 1938.

Standard Specifications for Electric-Fusion-Welded Steel Pipe (Sizes 8 in. to but not Including 30 in.) (A 139 - 36):[1]

Section 1.—Change the first sentence of this section to read as follows by the addition of the italicized words:

> These specifications cover two grades of electric-fusion-welded *straight-seam or spiral-seam* steel pipe in sizes 8 in. to but not including 30 in. in diameter, and wall thicknesses up to $\frac{5}{8}$ in., inclusive, which is intended for conveying liquid, gas, or vapor at temperatures below 450 F. and is adapted for flanging and bending.

Tentative revision, submitted August, 1938.

Section 6 (c).—Change Paragraph (c) to read as follows by the addition of the italicized words:

> (c) The tensile strength *taken perpendicularly* across the weld shall be not less than the minimum tensile strength of the grade of steel ordered.

Tentative revision, submitted August, 1938.

Section 7.—Change the first sentence of this section to read as follows by the addition of the italicized word:

> If required by the purchaser, the test specimen taken *perpendicularly* across the weld shall stand being bent cold through 180 deg. around a pin the diameter of which is equal to $4\frac{1}{2}$ times the thickness of the plate without developing cracks.

Tentative revision, submitted August, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

[2] See p. 586.

Section 9 (*a*).—Change the second sentence of Paragraph (*a*) to read as follows by the addition of the italicized word:

> Transverse tension test specimens shall be taken *perpendicularly* across the weld and from the same end of the pipe as the longitudinal test specimen.

Tentative revision, submitted August, 1938.

Standard Specifications for Axle-Steel Concrete Reinforcement Bars (A 160 - 36):[1]

Section 4 (*a*).—In the tabulation of tensile requirements change the values for Structural Steel Grade to read as follows by the addition of the italicized figures and words and the omission of the figures in brackets:

	STRUCTURAL STEEL GRADE	
	PLAIN BARS	DEFORMED BARS
Tensile strength, lb. per sq. in......	55 000 to [70 000] *75 000*	55 000 to [70 000] *75 000*
Elongation in 8 in. min., per cent...	$\frac{1\ 400\ 000}{\text{tens. str.}}$ *but not less than 20 per cent*	$\frac{1\ 250\ 000}{\text{tens. str.}}$ *but not less than 18 per cent*

Tentative revision, submitted August, 1938.

Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 - 35):[1]

Section 8 (*a*).—In the tabulation of tensile requirements make the same change as recommended above in Section 4 (*a*) of Specifications A 160.

Tentative revision, submitted August, 1938.

Standard Specifications for Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 - 36):[1]

Section 5.—In the table of chemical requirements following this section make the following changes in Grades C 1 and C 5:

Grade C 1.—Change the carbon content from "0.45 max. per cent" to read "0.35 max. per cent."

Tentative revision, submitted June, 1938.

Grade C 5.—Change the silicon content from "0.20 min. per cent" to read "0.20 to 1.50 per cent."

Tentative revision, submitted June, 1938.

Section 8 (*a*).—In the tabulation of tensile properties, change the values for Grade C 1 to read as follows by the addition of the italicized figures and the omission of those in brackets:

Tensile strength, lb. per sq. in.	[80 000] *70 000*
Yield point, lb. per sq. in....	[50 000] *45 000*
Elongation in 2 in., per cent.	22.0
Reduction of area, per cent..	[45.0] *35.0*

Tentative revision, submitted June, 1938.

Grade C 2.—Because the manganese-molybdenum type of steel, Grade C 2, is not in sufficiently wide usage to warrant its continuance in the specifications, it is proposed that it be deleted. This will involve a deletion of the reference to Grade C 2 in the following sections: Sections 1, Scope; 2, Process; 3, Heat Treatment Required; 5, Chemical Composition; 8, Tension Tests; and 17, Marking.

Tentative revision, submitted June, 1938.

Standard Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 - 36):[1]

Section 6.—Change from its present form to read as follows:

> 6. (*a*) Unless otherwise mutually agreed upon between the manufacturer and the purchaser, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress of 50 per cent of the minimum specified yield point at room temperature. This pressure shall be determined by the following formula:
>
> $$P = \frac{2\,S\,t}{D}$$
>
> where P = the minimum hydrostatic test pressure in pounds per square inch,

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[1] 1936 Book of A.S.T.M. Standards, Part I.

S = 0.50 times the minimum specified yield point at room temperature in pounds per square inch,

t = the nominal wall thickness in inches, and

D = the outside diameter in inches.

(*b*) The maximum hydrostatic test pressure shall not exceed 2500 lb. per sq. in. for sizes 3 in. or under in outside diameter, nor 4500 lb. per sq. in. for sizes over 3 in. in outside diameter. The hydrostatic pressure shall be maintained for not less than 5 sec.

Tentative revision, submitted June, 1938.

Section 7.—Change the first sentence of Paragraph (*a*) to read as follows by the addition of the italicized word:

(*a*) For welded pipe, the crop end cut from each end of each length of pipe shall be flattened *cold* between parallel plates with the weld located 90 deg. from the line of direction of the applied force, until opposite walls of the pipe meet.

Change Paragraph (*b*) to read as follows by the addition of the italicized words:

(*b*) For grade A seamless pipe over 2 in. in nominal diameter, a section of pipe not less than $2\frac{1}{2}$ in. in length shall be flattened *cold* between parallel plates until opposite walls of the pipe meet. No cracks or breaks in the metal shall occur until the distance between the plates is less than one third the outside diameter of the pipe, but in no case *shall the distance be* less than five times the thickness of the pipe wall. Evidence of laminations or burnt material shall not develop during the entire flattening process.

Make the same change in Paragraph (*c*) as is recommended above in Paragraph (*b*).

Tentative revision, submitted June, 1938.

Section 9 (c).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

(*c*) The transverse tension test may be made on seamless pipe 8 in. and over in nominal diameter. Specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests *subsequently normalized.* The specimen shall consist of a strip cut transversely from the pipe; the width of the specimen shall be $1\frac{1}{2}$ in. and its gage length 2 in. When the pipe wall thickness exceeds $\frac{3}{4}$ in., the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Specimens *cut from the ring section* [shall] *may* be flattened [cold] *hot* and shall be parallel between gage marks. At the option of the manufacturer, the transverse tension test specimen may be machined off on either surface provided not over 15 per cent of the nominal thickness is removed from either side.

Tentative revision, submitted June, 1938.

Table I.—Change Note 2 to Table I to read as follows by the omission of the words in brackets:

NOTE 2.—The decimal thicknesses listed for the respective pipe sizes represent their nominal or average wall dimensions [and include an allowance for mill tolerance of 12.5 per cent under the nominal thicknesses].

Omit Footnote "b" which reads as follows:

The schedule numbers indicate approximate values of the expression: $1000 \times \frac{P}{S}$; where P = the internal pressure in pounds per square inch and S = the allowable fiber stress in pounds per square inch.

Tentative revision, submitted June, 1938.

Section 13 (a).—Change the first sentence of this paragraph to read as follows by the addition of the italicized words and the omission of those in brackets:

The weight of any length of pipe shall not vary by more than 3.5 per cent under and 6.5 per cent over for pipe of Schedule Nos. 10 to 120, inclusive, nor more than 3.5 per cent under and 10 per cent over for pipe [of Schedule Nos. 140 and 160] *heavier than Schedule No. 120.*

Tentative revision, submitted June, 1938.

Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 - 33):[1]

Section 1 (d).—Change to read as follows by the omission of the words in brackets:

(*d*) [Carbon-steel] Nuts and washers for use with this bolting material are covered in Section 16.

Tentative revision, submitted June, 1938.

Section 16.—Change from its present form: namely,

16. Bolts and studs shall be equipped with semi-finished nuts of American Standard heavy dimensions, chamfered and trimmed.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

TABLE I.—MAXIMUM SERVICE PRESSURES FOR POWER PIPING AND OIL PIPING AT TEMPERATURES BELOW AND ABOVE 750 F.

Primary Service Pressure Rating at 750 F., lb. per sq. in.	100	300	400	600	900	1500
SERVICE TEMPERATURE, DEG. FAHR.	MAXIMUM SERVICE PRESSURES, LB. PER SQ. IN.					
POWER PIPING AND OIL PIPING						
100	230	500	670	1000	1500	2500
150	220	480	640	960	1440	2400
200	210	465	620	930	1395	2325
250	200	450	600	900	1350	2250
300	190	435	580	870	1305	2175
350	180	420	560	840	1260	2100
400	170	405	540	810	1215	2025
450	160	390	520	780	1170	1950
500	150	375	500	750	1125	1875
550	140	360	480	720	1080	1800
600	130	345	460	690	1035	1725
650	120	330	440	660	990	1650
700	110	315	420	630	945	1575
750	100	300	400	600	900	1500
POWER PIPING						
800	85	250	335	500	750	1250
850	70	200	270	400	600	1000
OIL PIPING						
800	92	275	370	550	830	1380
850	82	245	330	490	740	1230
900	70	210	280	420	630	1050
950	55	165	220	330	495	825
1000	40	120	160	240	360	600

Reference may be made to the dimensional standards for hydraulic pressure ratings and corresponding temperatures formulated by the Sectional Committee on Standardization of Pipe Flanges and Fittings, under the procedure of the American Standards Association, A.S.A. Project B 16 and more specifically to the American Standard for Steel Flanged Fittings and Companion Flanges, B 16*e* – 1932. Copies of this American Standard are obtainable from the American Standards Association or from the American Society of Mechanical Engineers, 29 West 39th St., New York City.

Tentative revision, submitted June, 1934; Modified, August, 1934.

If washers are used under nuts they shall be of forged or rolled steel. All nuts and washers shall be free from injurious defects and shall have a workmanlike finish. Nuts shall conform to the chemical requirements for phosphorus and sulfur as follows:

	CLASS I	CLASS II
Phosphorus, per cent, not over	0.045	0.05
Sulfur, per cent, not over	0.05	0.15

to read as follows:

16. Bolts and studs shall be equipped with semi-finished nuts of American Standard heavy dimensions, chamfered and trimmed. If washers are used under nuts they shall be of forged or rolled steel. All nuts and washers shall be free from injurious defects and shall have a workmanlike finish. Nuts shall conform to the requirements in the Tentative Specifications for Carbon- and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service to 1100 F. (A.S.T.M. Designation: A 194 – 38 T) of the American Society for Testing Materials.

Section 17.—Change this section to read as follows by the addition of the italicized words:

17. American National Standard coarse screw threads shall be used, except that no stud *or bolt* shall have less than eight threads per inch.

Tentative revision, submitted June, 1934.

Explanatory Note.—Change the Explanatory Note, appearing at the end of these specifications, to read as follows:

NOTE.—Allowable pressures and their corresponding allowable temperatures are given in the accompanying Table I. Higher temperatures with appropriate pressures may be used at the discretion of the designing engineer.

Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 - 36):[1]

New Section.—Add a new section designated as Section 5 on Forging Practice to read as follows, renumbering the subsequent sections accordingly:

5. (*a*) *Forging Practice.*—Material for forgings shall consist of blooms, billets, slabs, or bars either forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

(*b*) Forging or rolling operations may be performed either by hammering, pressing, rolling, extruding, or upsetting. Forgings shall be brought as nearly as practicable to the finished shape and size by hot working and shall be so processed as to cause metal flow during the hot-working operation in the direction most favorable for resisting the stresses encountered in service.

(*c*) When specified in the purchase order, a sample forging may be sectioned and etched to show flow lines and the condition as regards internal imperfections. In such cases, the question of acceptable and unacceptable character of metal flow shall be a subject for agreement between the purchaser and the manufacturer.

(*d*) When specified in the purchase order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

Tentative revision, submitted June, 1938.

Section 6 (b).—Change to read as follows by the addition of the italicized words:

(*b*) The carbon content of Class I and II material shall be a matter of agreement between the purchaser and the manufacturer, *but the carbon content for flanges to be welded shall not exceed 0.35 per cent.*

Tentative revision, submitted June, 1938.

Section 10 (d).—Change from its present form: namely,

(*d*) For purposes of testing, the necessary extra flanges shall be provided to furnish the specimens required in Paragraph (*a*). The test specimen shall be cut tangentially from the flange portion approximately midway between the inner and outer surfaces and approximately midway between the front and back faces.

to read as follows:

(*d*) For the purpose of making tension tests specified in Paragraph (*a*) the manufacturer shall supply suitable test specimens from the flange or at his option furnish test specimens cut from the billets or forging bar entering into the finished product, providing such test specimen has undergone approximately the same working and heat treatment as the finished product.

Tentative revision, submitted June, 1938.

Standard Specifications for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F. (A 182 - 36):[1]

Section 7 (c).—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

(*c*) Tempering or Drawing.—The procedure for tempering or drawing shall consist in reheating the forgings to a temperature at least [200] *100* F. ([93] *38* C.) above the temperature to be encountered in service, [holding at that temperature] *but in no case shall the drawing temperature be lower than 850 F. and for Grade F6 the minimum drawing temperature shall be 1150 F. The material shall be held at the required temperature* for not less than 1 hr. per inch of thickness at the thickest section, followed by cooling in the furnace or in still air.

Tentative revision, submitted June, 1938.

Section 8.—In the table of chemical composition change the chromium content range for Grade F6 from "11.5 to 13.0 per cent" to read "11.5 to 13.5 per cent."

Tentative revision, submitted June, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

Standard Specifications for Spiegeleisen (A 98 - 27):[1]

The Tentative Specifications for Spiegeleisen (A 98 – 38 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 98 – 27.

Tentative revision, submitted August, 1938.

Standard Specifications for Ferromanganese (A 99 - 27):[1]

The Tentative Specifications for Ferromanganese (A 99 – 38 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 99 – 27.

Tentative revision, submitted August, 1938.

Standard Specifications for Ferrosilicon (A 100 - 27):[1]

The Tentative Specifications for Ferrosilicon (A 100 – 38 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 100 – 27.

Tentative revision, submitted August, 1938.

Standard Specifications for Ferrochromium (A 101 - 27):[1]

The Tentative Specifications for Ferrochromium (A 101 – 38 T)[5] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 101 – 27.

Tentative revision, submitted August, 1938.

Standard Specifications for Ferrovanadium (A 102 - 27):[1]

The Tentative Specifications for Ferrovanadium (A 102 – 38 T)[6] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 102 – 27.

Tentative revision, submitted August, 1938.

Standard Specifications for Molybdenum Salts and Compounds (A 146 - 34):[1]

The Tentative Specifications for Molybdenum Salts and Compounds (A 146–38 T)[7] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 146 – 34.

Tentative revision, submitted August, 1938.

Standard Specifications for Ferromolybdenum (A 132 - 34):[1]

The Tentative Specifications for Ferromolybdenum (A 132 – 38 T)[8] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 132 – 34.

Tentative revision, submitted August, 1938.

Standard Specifications for Low-Carbon Ferromolybdenum (A 145 - 34):[1]

The Tentative Specifications for Ferromolybdenum (A 132 – 38 T)[8] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 145 – 34.

Tentative revision, submitted August, 1938.

Standard Specifications for Ferrotungsten (A 144 - 34):[1]

The Tentative Specifications for Ferrotungsten (A 144 – 38 T)[9] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 144 – 34.

Tentative revision, submitted August, 1938.

Standard Specifications for Welded Wrought-Iron Pipe (A 72 - 38):[1]

Section 2.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

2. (*a*) The pipe shall be made from *all pig puddled or processed* wrought iron and shall be free from any admixture of iron scrap or steel.

Tentative revision, submitted June, 1937.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

[2] See p. 615.

[3] See p. 617.

[4] See p. 619.

[5] See p. 621.

[6] See p. 623.

[7] See p. 629.

[8] See p. 625.

[9] See p. 627.

Tentative Revision of Standard Specifications for Iron and Steel Chain (A.S.T.M. Designation: A 56 – 30):[1]

Section 1.—Change the second paragraph to read as follows by the addition of the italicized word and the omission of the word in brackets:

Crane Chain, for slings, [hoists] ***cranes***, steam shovels, and marine uses, and where an all-iron chain is desired.

Revision submitted, August, 1937.

Section 2.—Change the paragraph covering crane chain to read as follows by the addition of the italicized words:

Crane Chain.—Crane Chain shall be made from ***all pig puddled or processed*** wrought iron free from any admixture of iron scrap or steel.

Revision submitted, June, 1937.

Change the paragraph covering proof coil from its present form: namely,

Proof Coil.—Proof coil may be made from open-hearth steel or all reworked scrap.

NOTE.—The term "reworked scrap" applies to steel and iron scrap, or a mixture of both.

to read as follows, omitting the note defining "reworked scrap:"

Steel Proof Coil.—Proof coil shall be made from open-hearth steel.

Revision submitted, August, 1937.

Table I.—Change the present proof test loads for crane chain wrought iron appearing in the second column of Table I by substituting the values shown in the following table under Proposed Revised Proof Test Loads; the new requirements being 38 per cent of the breaking load:

	CRANE CHAIN WROUGHT IRON	
NOMINAL SIZE OF CHAIN BAR, IN.	PRESENT PROOF TEST LOADS	PROPOSED REVISED PROOF TEST LOADS
$\frac{1}{4}$	1 767	1 345
$\frac{5}{16}$	2 760	2 100
$\frac{3}{8}$	3 975	3 020
$\frac{7}{16}$	5 415	4 115
$\frac{1}{2}$	7 072	5 375
$\frac{9}{16}$	8 947	6 800
$\frac{5}{8}$	11 047	8 395
$\frac{3}{4}$	15 900	12 080
$\frac{7}{8}$	21 622	16 430
1	28 275	21 490
$1\frac{1}{8}$	33 400	25 380
$1\frac{1}{4}$	41 250	31 350
$1\frac{3}{8}$	49 900	37 920
$1\frac{1}{2}$	59 350	45 100
$1\frac{5}{8}$	69 750	53 000
$1\frac{3}{4}$	80 800	61 400
$1\frac{7}{8}$	92 750	70 500
2	105 500	80 200

Revision submitted, August, 1937.

New Section.—Add the following requirements for marking as a new Section 14 renumbering the present Sections 14 to 16 accordingly:

14. *Marking.*—No markings shall be stamped on any links of the chain. Metal tags with the words, "Crane" or "Proof Coil" stamped thereon shall be securely attached to each end of each chain.

Revision submitted, August, 1937.

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[1] **1936 Book of A.S.T.M. Standards, Part I.**

Section 4.—Change the table of requirements as to chemical composition to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

	WROUGHT IRON CRANE CHAIN	STEEL PROOF COIL
Manganese, maximum, per cent	[0.10] *0.06*	....
Phosphorus, maximum, per cent	....	0.05
Sulfur, maximum, per cent	....	0.05

Revision submitted, August, 1937.

Tentative Revision of Standard Specifications for Uncoated Wrought-Iron Sheets (A.S.T.M. Designation: A 162 – 36):[1]

Section 2.—Change to read as follows by the addition of the italicized words:

2. All sheets shall be rolled from slabs, piles or bars made from *all pig puddled, knobbled charcoal or processed* wrought iron and shall be free from any admixture of iron scrap (Note) or steel.

Revision submitted, June, 1937.

Tentative Revision of Standard Specifications for Zinc-Coated (Galvanized) Wrought-Iron Sheets (A.S.T.M. Designation: A 163 – 36):[1]

Section 2.—Change to read as follows by the addition of the italicized words:

2. All sheets shall be rolled from slabs, piles or bars made from *all pig puddled or processed* wrought iron and shall be free from any admixture of iron scrap (Note) or steel.

Revision submitted, June, 1937.

Tentative Revision of Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings (A.S.T.M. Designation: A 73 – 36):[1]

Section 2.—Change the first sentence of Paragraph (*a*) to read as follows by the addition of the italicized words:

Blooms and forgings of Class A shall be made from *all pig puddled or processed* wrought iron and shall be free from any admixture of iron scrap or steel.

Revision submitted, June, 1937.

Tentative Revision of Standard Specifications for Staybolt Wrought Iron, Solid (A.S.T.M. Designation: A 84 – 36):[1]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

2. The bars shall be rolled from a [bloom,] slab pile or box pile made from [reworked wrought iron] *all pig puddled,* [or reworked] knobbled charcoal *or processed wrought* iron. The original muck [or knobbled] bars shall be [twice] piled *rolled, repiled* and rerolled. The [wrought iron and] component parts of the [bloom,] slab pile or box pile shall be free from any admixture of iron scrap or steel.

Revision submitted, June, 1937.

Section 3.—Omit Paragraph (*a*), which reads as follows, relettering the present Paragraphs (*b*) and (*c*) as Paragraphs (*a*) and (*b*), respectively:

3. (*a*) *Bloom.*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

Revision submitted, June, 1937.

Section 11.—Add a new Paragraph (*b*) to read as follows, relettering the present Paragraph (*b*) as Paragraph (*c*):

(*b*) Where small lots of different sizes are to be tested, the bas shall be grouped into lots of 50, or fraction thereof, without regard to size, and one bar representing the lot shall be tested as specified in Sections 6, 8 and 9.

Revision submitted, June, 1937.

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[1] **1936 Book of A.S.T.M. Standards, Part I.**

Section 12.—Change this section from its present form: namely,

12. The bars shall be truly round within 0.01 in. The diameter shall be not less than 0.005 in. over nor more than 0.020 in. over the specified diameter.

to read as follows:

12. (*a*) All bars shall be truly round within 0.010 in., and shall conform to the following requirements as to permissible variations in size:

NOMINAL DIAMETER OF BAR, IN.	MINIMUM	MAXIMUM	TOTAL ROLLING TOLERANCE
BARS FOR THREADING			
$\frac{7}{8}$	0.895	0.910	0.015
$\frac{15}{16}$	0.958	0.973	0.015
1	1.020	1.035	0.015
$1\frac{1}{16}$	1.083	1.098	0.015
$1\frac{1}{8}$	1.145	1.160	0.015
$1\frac{3}{16}$	1.208	1.223	0.015
$1\frac{1}{4}$	1.270	1.285	0.015
BARS FOR FORGING			
$\frac{7}{8}$	0.880	0.895	0.015
$\frac{15}{16}$	0.943	0.958	0.015
1	1.005	1.020	0.015
$1\frac{1}{16}$	1.068	1.083	0.015
$1\frac{1}{8}$	1.130	1.145	0.015
$1\frac{3}{16}$	1.193	1.208	0.015
$1\frac{1}{4}$	1.255	1.270	0.015
$1\frac{5}{16}$	1.318	1.333	0.015
$1\frac{3}{8}$	1.380	1.395	0.015
$1\frac{7}{16}$	1.443	1.458	0.015
$1\frac{1}{2}$	1.505	1.520	0.015
$1\frac{5}{8}$	1.630	1.645	0.015
$1\frac{3}{4}$	1.755	1.770	0.015
$1\frac{7}{8}$	1.880	1.895	0.015
2	2.005	2.020	0.015

Revision submitted, August, 1937.

Tentative Revision of Standard Specifications for Staybolt Wrought Iron, Hollow Rolled (A.S.T.M. Designation: A 86 – 36):[1]

Make the same changes in Sections 2, 3 and 11 of these specifications as are recommended in Specifications A 84, above. Revision submitted, June, 1937.

Make the same change in Section 12 (*a*) of these specifications as is recommended in Specifications A 84, above. Revision submitted, August, 1937.

Tentative Revision of Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 30):[1]

The Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 37 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications A 116 – 30. Revision submitted, June, 1937

Tentative Revision of Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A.S.T.M. Designation: A 121 – 30):[1]

The Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 37 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 121 – 30.

Revision submitted, June, 1937.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, pp. 646, 643 (1937); also 1938 Book of A.S.T.M. Tentative Standards, pp. 198, 201.

Standard Specifications for Gray-Iron Castings for Valves, Flanges, and Pipe Fittings (A 126 - 30):[1]

Section 1.—Change the second paragraph to read as follows by the addition of the italicized words and the omission of the word in brackets:

> [Two] *Three* classes of castings are included as follows:
>
> Class A.—Regular gray iron.
>
> Class B.—Higher-strength gray iron including the so-called semi-steels used in valves and fittings.
>
> *Class C.—High-test cast iron whether regular or alloy composition.*

Section 4 (a).—Change the table of tensile strength requirements to read as shown in Table I by the addition of the italicized words and figures and the omission of the figure in brackets.

TABLE I.

Class A, Regular gray iron	not less than 21 000 lb. per sq. in.
Class B, Higher-strength gray iron	not less than [30 000] *31 000* lb. per sq. in.
Class C	*not less than 41 000 lb. per sq. in.*

TABLE II.

	Class A REGULAR GRAY IRON	*Class B* HIGHER-STRENGTH GRAY IRON	*Class C*
Load at center, lb.	not less than [2500] *2200*	not less than 3300	*not less than 4000*
Deflection at center, in.	not less than 0.10	not less than 0.12	*not less than 0.12*

Section 5 (a).—Change the table of transverse strength requirements to read as shown in Table II by the addition of the italicized words and figures and the omission of the figure in brackets.

Tentative revision, submitted June, 1938.

Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 - 27):[1]

The Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Sheets (A 93 - 38 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 93 - 27.

Tentative revision, submitted August, 1938.

Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 - 38):[1]

The Tentative Method of Test for Measuring Interlamination Resistance of Steel (A 34 - 38 T)[3] is in effect a tentative revision of and is intended to be added when adopted to the present Standard A 34 - 38.

Tentative revision, submitted June, 1938.

Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 - 36):[1]

Weber.—Under the Definitions of Units, add a definition for "weber," a unit of magnetic flux, to read as follows:

> *Weber.*—The amount of magnetic flux which, when linked at a uniform rate with a single-turn electric circuit during an interval of one second, will induce in this circuit an electromotive force of one volt.

Tentative revision, submitted June, 1938.

Magnetic Induction.—Change from its present form: namely,

> *Magnetic Induction* (*Magnetic Flux Density*), *B.*—The vector magnetic quantity which, at any point in a magnetic field, determines the electromotive force induced in an electric circuit which is linked with the field at a definite time rate. Thus:
>
> $$e = N\frac{dB}{dt}$$
>
> where e is the electromotive force produced in a circuit which is linked N times with a magnetic field of unit cross-sectional area and of uniform induction B.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

[2] See p. 602.

[3] See p. 631.

NOTE.—In isotropic materials, magnetic induction and magnetizing force have the same (or opposite) direction. In anisotropic materials (such as single crystals and fabricated metals) the direction of the induction is a function of the magnitude of the magnetizing force, the orientation of the crystal axes of the material and its previous condition of magnetization.

UNIT: *Gauss.*

to read as follows:

*Magnetic **Induction**, B.*—A vector quantity which, at any point in a magnetic field, determines the electromotive force induced in an elementary conductor that is moving through the field at that point. The value of the electromotive force is proportional to the component of the magnetic induction which is perpendicular to the plane in which the conductor moves, as well as to the product of the length of the conductor, its velocity, and the sine of the angle between the direction of the conductor and the direction of motion. In a vacuum, magnetic induction at a point has the same direction as, and is proportional in magnitude to, the magnetizing force at the point. In material media, magnetic induction is a function of the configurations of the electrons and atoms of the material.

The vector equation connecting magnetic induction and electromotive force is:

$$e = V \times L \times B$$

where L is the length of a conductor moving with velocity V perpendicular to a uniform field of magnetic induction B, and e is the electromotive force produced, all quantities being measured in the same system of units.

NOTE.—In isotropic materials magnetic induction and magnetizing force have the same (or opposite) direction. In anisotropic materials (such as single crystals and fabricated metals) the direction of the induction is a function of the magnitude of the magnetizing force, the orientation of the crystal axes of the material and its previous condition of magnetization.

UNIT: *Gauss.*

Tentative revision, submitted June, 1938.

Intrinsic Induction.—Change from its present form: namely,

Intrinsic Induction in a Ferromagnetic Material (Ferric Induction), B_i.—For a given value of the magnetizing force, the excess of the normal induction in the material over that in vacuum.

$$B_i = B - \mu_v H$$

UNIT: *Gauss.*

to read as follows:

Intrinsic Induction, B_i.—At any point in a magnetic body, the excess of the induction at the point over that produced in a vacuum by a magnetizing force of the value acting at the point. Thus:

$$B_i = B - \mu_v H$$

UNIT: *Gauss.*

Tentative revision, submitted June, 1938.

Standard Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (B 8 - 36):[1]

The Tentative Specifications for Bare Stranded Copper Cable, Hard, Medium-Hard, or Soft (B 8 – 38 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard B 8 – 36.

Tentative revision, submitted June, 1938.

Standard Specifications for Aluminum-Bronze Castings (B 59 - 38):[3]

Section 3.—Change the chemical composition requirements for Grade A bronze from their present form: namely,

	GRADE A
Copper, per cent	87 to 89
Aluminum, per cent	7 to 9
Iron, per cent	2.5 to 4
Tin, max., per cent	0.5
Total other impurities, max., per cent	1.0

to read as follows:

	GRADE A
Copper, min., per cent	86.0
Aluminum, per cent	8.0 to 9.5
Iron, per cent	2.5 to 4.0
Tin, max., per cent	0.50
Total other impurities, max., per cent	1.00

Tentative revision, submitted August, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

[2] See p. 677.

[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 84.

Tentative Revision of Standard Specifications for Manganese-Bronze Ingots for Sand Castings (A.S.T.M. Designation: B 7 – 27):[1]

Section 3.—Change the table of chemical requirements appearing in this section to read as follows by the addition of the italicized words and figures and the omission of the figures in brackets:

	MAXIMUM	MINIMUM
Copper, per cent	[60] *62.0*	55.0
Zinc, per cent	[42] *remainder*	[38] *remainder*
Tin, per cent	1.5	0.0
Manganese, per cent	3.5	[0.0] *0.2*
Aluminum, per cent	1.5	[0.0] *0.5*
Iron, per cent	2.0	[0.0] *0.6*
Lead, per cent	[0.2] *0.4*[a]	0.0

[a] In the case of the Specifications for Castings (B 54) the present requirement for lead is 0.4 per cent; the proposed change is intended to apply only to the lead content requirement in the Specifications for Ingots (B 7).

Revision submitted, June, 1936.

Tentative Revision of Standard Specifications for Manganese-Bronze Sand Castings (A.S.T.M. Designation: B 54 – 27):[1]

Section 3.—Make the same change in this section as recommended in Section 3 of Specifications B 7 – 27, above.

Revision submitted, June, 1936.

Tentative Revision of Standard Specifications for Rolled Zinc (A.S.T.M. Designation: B 69 – 29):[1]

The Tentative Specifications for Rolled Zinc (B 69 – 37 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications B 69 – 29.

Revision submitted, June, 1937.

Tentative Revision of Standard Specifications for Quicklime for Structural Purposes (A.S.T.M. Designation: C 5 – 26):[3]

The Tentative Specifications for Quicklime for Structural Purposes (C 5 – 34 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard C 5 – 26.

Revision submitted, June, 1934.

Tentative Revision of Standard Specifications for Hydrated Lime for Structural Purposes (A.S.T.M. Designation: C 6 – 31):[3]

The Tentative Specifications for Hydrated Lime for Structural Purposes (C 6 – 34 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard C 6 – 31.

Revision submitted, June, 1934.

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[1] 1936 Book of A.S.T.M. Standards, Part I.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 698 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 406.

[3] 1936 Book of A.S.T.M. Standards, Part II.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 749, 752 (1934); also 1938 Book of A.S.T.M. Tentative Standards, pp. 494, 498.

Standard Specifications for Clay Sewer Pipe (C 13 - 35):[1]

Table I.—Change the table of physical test requirements to read as follows by the addition of the italicized figures and the omission of those in brackets:

TABLE I.—PHYSICAL TEST REQUIREMENTS OF CLAY SEWER PIPE.

Internal Diameter, in.	Average Crushing Strength, minimum, lb. per linear foot		Average Absorption, maximum, per cent
	Three-Edge-Bearing Method[1]	Sand-Bearing Method[2]	
4	1000	1430	8
6	1000	1430	8
8	1000	1430	8
10	1100	1570	8
12	1200	1710	8
15	1370	1960	8
18	[1540] *1665*	[2200] *2375*	8
21	[1810] *1995*	[2590] *2850*	8
24	[2150] *2400*	[3070] *3125*	8
27	[2360] *2765*	[3370] *3950*	8
30	[2580] *3170*	[3690] *4525*	8
33	[2750] *3535*	[3930] *5050*	8
36	[3080] *3900*	[4400] *5575*	8

[1] See Section 14. [2] See Section 15.

Tentative revision, submitted August, 1938.

Table II.—In the table of dimension for clay sewer pipe change the sentence under the last column to read as follows by the addition of the italicized word:

> The thickness of the socket ½ in. from its outer end shall be not less than three-fourths of the *specified* thickness of the barrel of the pipe.

Tentative revision, submitted June, 1938.

Standard Specifications for Fireclay Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 - 36):[1]

Section 2.—Change this section covering permissible variations in size from its present form: namely,

> 2. Variations of ±2 per cent from specified dimensions covering both shrinkage and warpage shall be allowed on dimensions of 4 in. or over. On dimensions under 4 in., variations of ±3 per cent shall be allowed. These permissible variations apply in general throughout these specifications.

to read as follows:

> 2. (*a*) Fireclay brick shall conform to specified dimensions as to size within the following permissible variations:

DIMENSION	PERMISSIBLE VARIATION
4 in. or over	±2 per cent
Under 4 in.	±3 per cent

> (*b*) The permissible variations in size specified in Paragraph (*a*) shall apply in general throughout these specifications.

Tentative revision, submitted June, 1938.

New Section.—Add a new section, designated Section 3 covering permissible variations in warpage, to read as follows, renumbering the subsequent sections accordingly:

> 3. Ninety-five per cent of the shapes shall not show a warpage greater than ⅛ in. per linear ft. of the diagonal used in making the measurement.

Tentative revision, submitted June, 1938.

Standard Specifications for Fireclay Brick for Stationary Boiler Service (C 64 - 36):[1]

Make the same change in Section 2 and add a new Section 3 to these specifications as recommended above in Specifications C 63.

Tentative revision, submitted June, 1938.

Standard Specifications for Fireclay Brick for Marine Boiler Service (C 65 - 28):[1]

Make the same change in Section 2 and add a new Section 3 to these specifications as recommended above in Specifications C 63.

Tentative revision, submitted June, 1938.

Standard Specifications for Refractories for the Construction of Incinerators (C 106 - 36):[1]

Make the same change in Section 3 of these specifications as is recommended above in Specifications C 63.

Tentative revision, submitted June, 1938.

Standard Specifications for Keene's Cement (C 61 - 30):[1]

Section 3.—Change this section to read as follows by the addition of the italicized figures and the omission of those in brackets:

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[1] 1936 Book of A.S.T.M. Standards, Part II.

3. The cement shall have a tensile strength of not less than [450] *400* lb. per sq. in. ([31.5] *28.2* kg. per sq. cm.).

Tentative revision, submitted June, 1938.

Section 8.—Change this section to read as follows by the addition of the italicized figures and the omission of those in brackets:

8. The chemical and physical properties of Keene's cement shall be determined in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (A.S.T.M. Designation: C 26) of the American Society for Testing Materials, except that in the determination of the time of setting and tensile strength the consistency used shall be such that a [350] *150*-g. modified Vicat needle, described in Section 15 of the Standard Methods C 26 shall give a penetration of 20 mm. ± 2 mm., 20 sec. after release, the measurement being made [20] *5* min. after the addition of the Keene's cement to the gaging water.

Change the note following this section from its present form: namely,

NOTE.—A 20-min. mixing-and-soaking period for the Keene's cement and water, with occasional stirring to remove entrained air or gas bubbles, is required as follows:

(*1*) Before the determination of testing consistency.

(*2*) Before the determination of time of setting (the soaking time to be included in the time of setting).

(*3*) Before filling the molds in the strength determinations.

The use of 0.1 per cent retarder in determining testing consistency is optional.

to read as follows:

NOTE.—A 20-min. mixing and soaking period for the Keene's cement and water with occasional stirring to remove entrained air or gas bubbles is required before filling the molds in the strength determination. The use of 0.1 per cent retarder in determining the testing consistency is necessary when working with quick-setting cements.

Tentative revision, submitted June, 1938.

Standard Specifications for Gypsum Plasters (C 28 - 30):[1]

Section 7.—Change this section to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

7. Gypsum neat plaster when mixed with three parts by weight of testing sand shall set in not less than [8] *2* hr., nor more than 32 hr.

Tentative revision, submitted June, 1938.

Section 8.—Change this section to read as follows by the addition of the italicized words and figures and the omission of the figures in brackets:

8. Gypsum neat plaster *as tested with two parts of standard Ottawa sand* shall have a tensile strength of not less than [150] *75* lb. per sq. in. ([10½] *5.14* kg. per sq. cm.).

Tentative revision, submitted June, 1938.

Standard Method of Testing Gypsum and Gypsum Products (C 26 - 33):[1]

Section 20.—Change the test for time of setting as described in this section from its present form: namely,

20. Mix 200 g. of the sample (Note) with enough water to make a paste of testing consistency as described in Sections 14 to 16.

NOTE.—When the sample to be tested is a sanded mixture, use 300 g. and mix to testing consistency for sanded mixture.

Fill a mold with the paste, and test for time of set with a Vicat needle. The specifications for the mold and needle are given in Sections 23 and 32 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials.

When conducting the test, the needle is allowed to sink into the paste at frequent intervals. After each penetration, the needle must be wiped clean, and the paste moved slightly so that the needle will not strike the same hole twice.

The frequency of the penetrations will depend upon the character of the material. If the sample is not retarded, it should be tested every two minutes until nearly set, and then every minute. If the sample is retarded, the intervals at first may be as long as one hour, but in any case they shall be so selected that the time of set is ascertained to the nearest minute.

Set is considered complete when the needle no longer penetrates to the bottom of the paste. The minutes elapsed, from the time when the sample was first added to the water, to the time when set is complete, are recorded as the time of set of the sample.

Caution: For test to determine the time of set, it is absolutely essential that all dishes and utensils be clean. Especially must they be free from all traces of set gypsum. Use distilled water.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

to read as follows:

20. (*a*) *All Calcined Gypsum Products, Except Neat Gypsum Plaster.*—A 200-g. sample (Note) shall be mixed with enough water to make a paste of testing consistency as described in Sections 14 to 16. The paste shall be placed in the conical ring and, after completely filling the ring, the paste shall be tested for final set with a Vicat needle. The specifications for the conical ring and the needle are given in Section 29 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials. When conducting the test, the needle shall be allowed to sink into the paste at frequent intervals. After each penetration, the needle shall be wiped clean, and the paste moved slightly so that the needle will not strike the same hole twice. The frequency of the penetration will depend upon the character of the material. If the sample is not retarded, it shall be tested every 2 min. until nearly set, and then every 1 min. If the sample is retarded, it shall be tested at such intervals as are necessary to determine whether it complies with the requirements of time of setting for the product tested. Set shall be considered complete when the needle no longer penetrates to the bottom of the paste. The minutes elapsed, from the time when the sample was first added to the water, to the time when set is complete, shall be recorded as the time of setting of the sample.

NOTE.—When the material to be tested is gypsum ready-mixed sanded plaster a 300-g. sample shall be used and mixed to testing consistency for sanded mixture.

(*b*) *Neat Gypsum Plasters.*—Neat gypsum plasters shall be tested for time of setting as mixed with three parts by weight of standard Ottawa sand which has been washed and dried in accordance with the procedure described in Section 13 (*c*). A 100-g. sample of the neat gypsum plaster and 300 g. of testing sand shall be mixed dry and then sufficient water added to produce a mixture of testing consistency for sanded gypsum mixtures as described in Section 14 (*b*). The mortar shall be placed in the conical rings and tested for time of setting as described in Paragraph (*a*). The test pieces shall be stored in a cabinet at a temperature of not less than 20 C. (68 F.) nor more than 22.2 C. (72 F.) in an atmosphere of not less than 85 nor more than 100 per cent relative humidity until set. The test pieces shall not be tested with the Vicat needle until they show evidence of stiffening or setting. Excessive penetration of the mix with the needle tends to accelerate the setting time. For plaster setting in under 5 hr. the setting time shall be determined to the nearest 15-min. interval, and for plaster setting in over 5 hr., to the nearest 30-min. interval.

Tentative revision, submitted June, 1938.

Section 22.—Designate this section as 22 (*a*) and add the following new heading: "All calcined gypsum products except gypsum neat plasters."

Change the note at the end of this section from its present form: namely,

NOTE.—When the material to be tested is a sanded mixture, use not less than 750 g. and mix to testing consistency for sanded mixture.

to read as follows:

NOTE.—When the material to be tested is gypsum ready-mixed sanded plaster a sample of not less than 750 g. shall be used and mixed to testing consistency for sanded mixture.

Add a new paragraph (*b*) to this section to read as follows:

(*b*) *Gypsum Neat Plaster.*—Gypsum neat plaster, both fibered and unfibered, shall be tested for tensile strength as mixed with two parts of standard Ottawa sand, fibered plaster shall be screened through a No. 6 sieve to remove the major portion of the long fibers present. A 250-g. sample of the neat gypsum plaster and 500 g. of standard Ottawa sand shall be mixed dry and then sufficient water added to produce a mixture of testing consistency in accordance with Section 14 (*b*). The mortar shall be cast into molds as described in Section 21 and in Paragraph (*a*) of this section, except that the molds shall be so filled as to allow a slight excess of the mortar to extend above the top of the molds. After the mortar has set, the excess mortar shall be screeded from the top of the molds with a broad knife or similar implement. The mortar briquets shall be dried and tested as described in Paragraph (*a*).

Tentative revision, submitted June, 1938.

Section 26.—Add the following new test for determining sand in set plaster as new Sections 26 to 29, renumbering the present sections accordingly:

DETERMINATION OF SAND IN SET PLASTER

26. *Ammonium Acetate Method.*—Any method for the determination of the sand content of set gypsum plaster requires for accurate results the following determinations:

(*a*) Determination of the percentage of insoluble matter in the sand used with the plaster,

(*b*) Determination of the percentage of insoluble matter in the neat gypsum plaster, and (*c*) Determination of the percentage of insoluble matter in the sanded calcined plaster.

NOTE.—If samples of the original gypsum neat plaster and the sand are not available, an approximation of the insoluble matter may be obtained by use of this method on plaster and sand from the same sources as those from which the plaster to be analyzed was originally prepared.

27. *Sampling.*—Where plaster to be tested is part of a 2-coat or 3-coat plastering operation, the sample for analysis shall be taken from that portion of the entire plaster sheet which comprises the single coat being tested. Succeeding coats of plaster shall be separated by use of a stiff putty knife or similar implement. At least 500 g. shall be taken as a sample, the sample preferably being obtained from different sections of the wall or ceiling under examination.

28. *Procedure.*—(*a*) In a clean porcelain mortar, grind the set plaster sample to the size of the largest sand particles present, or smaller, so that approximately 100 per cent of the sample will pass a No. 8 sieve. Fine grinding makes solution of the gypsum faster. Place about 200 g. of the ground sample in a porcelain casserole or evaporating dish and calcine on a sand bath. Stir the sample continuously with a thermometer during the heating and adjust the rate of heating so that 20 to 30 min. will be required to raise the temperature of the sample to 160 ± 5 C. Cool the sample to room temperature.

(*b*) After cooling, weigh accurately 20 ± 0.05 g. of the calcined sample into a 600-ml. beaker. Add 300 to 350 ml. of ammonium acetate (25 per cent) which should be slightly alkaline to litmus paper. If acidic, add a few milliliters of dilute ammonium hydroxide (1 per cent) to the stock solution of ammonium acetate to render it slightly alkaline prior to the addition to the test sample.

(*c*) Warm the suspension to a temperature of 70 ± 5 C. and stir continuously for 20 to 30 min. Filter the warm suspension with the aid of suction through a small Büchner funnel or Gooch crucible in which an asbestos mat or filter paper has previously been formed, the funnel and mat having been dried at 110 C. to constant weight within 0.01 g. Refilter the first 100 ml. of the filtrate. Wash the sand remaining in the beaker onto the filter with an additional 100 ml. of warm ammonium acetate solution. Wash the beaker and residue with 200 to 300 ml. of water, dry the funnel and sand at 100 C. to constant weight. Subtract the weight of the residue from the original weight of the sample to obtain the weight of the insoluble content.

(*d*) *Percentage of Insoluble Matter in Plaster.*—Multiply the weight of the insoluble content obtained in Paragraph (*c*) by 5 to obtain the percentage of insoluble matter in the sanded plaster.

(*e*) *Percentage of Insoluble Matter in Sand.*—Determine the weight of insoluble matter in the sand as described in Paragraphs (*a*) to (*c*), except that no grinding of the sample is necessary. Multiply the weight of the insoluble matter obtained by 5 to obtain the percentage of insoluble matter in the sand.

(*f*) *Percentage of Insoluble Matter in Neat Gypsum Plaster.*—Determine the weight of insoluble matter in the neat gypsum plaster as described in Paragraphs (*a*) to (*c*), except that only a 5-g. sample is required and no grinding of the sample is necessary. Multiply the weight of the insoluble content obtained by 20 to obtain the percentage of insoluble matter in the neat gypsum plaster.

29. (*a*) *Calculations.*—The percentage of sand in the sanded plaster shall be calculated by means of the following formula:

$$X = \frac{(C - B)\ 100}{A - B}$$

where X = the percentage of sand in the sanded plaster,
A = the percentage of insoluble matter in the sand,
B = the percentage of insoluble matter in the gypsum neat plaster, and
C = the percentage of insoluble matter in the sanded plaster,

(*b*) To express the results as a ratio of the parts of sand per part of plaster by weight, the following formula may be used:

$$\text{Ratio of sand to plaster} = \frac{X}{100 - X}$$

NOTE.—The results obtained by the above procedure, indicate the amount of sand originally mixed with the gypsum neat plaster before it had been gaged with water or set.

Tentative revision, submitted June, 1938.

Standard Specifications for Structural Clay Load-Bearing Wall Tile (C 34-36):[1]

The Tentative Specifications for Structural Clay Load-Bearing Wall Tile (C 34 – 38 T)[2] are in effect a tentative revision of and are intended to replace when adopted the present Standard C 34 – 36.

Tentative revision, submitted June, 1938.

Standard Specifications for Structural Clay Non-Load-Bearing Tile (C 56-36):[1]

Section 3.—Add to this section on weights of tile a new Paragraph (*b*) to read as follows, designating the present section as Paragraph (*a*):

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[1] 1936 Book of A.S.T.M. Standards, Part II.
[2] See p. 779.

> (*b*) The requirements for minimum weights of structural clay non-load-bearing **tile** shall be waived if the over-all thickness of the shells, measured between the inner and extreme outer surfaces, is not less than $\frac{5}{8}$ in. and the thickness of the webs is not less than $\frac{1}{2}$ in.

Tentative revision, submitted June, 1938.

Standard Specifications for Structural Clay Floor Tile (C 57 - 36):[1]

Section 3.—Add to this section on weights of tile a new Paragraph (*c*) to read as follows:

> (*c*) The requirements for minimum weights of structural clay floor tile shall be waived if the over-all thickness of the shells, measured between the inner and extreme outer surfaces, is not less than $\frac{5}{8}$ in. and the thickness of the webs is not less than $\frac{1}{2}$ in.

Tentative revision, submitted June, 1938.

Standard Method of Test for Structural Strength of Fine Aggregate Using Constant Water-Cement-Ratio Mortar (C 87 - 36):[1]

Section 2.—Change the third sentence from its present form: namely,

> Saturated and surface-dried sand from a sample of known weight[a] shall be beaten into the mixture until the material appears to be of the desired consistency (flow 100 ± 5).
>
> ---
>
> [a] For six 2-in. cubes, 600 g. of cement and 359 cc. of water will usually give sufficient mortar. The quantity of sand used with this amount of cement may vary from 1200 g. for fine sand to 2000 g. or more for coarse sand.

to read as follows:

> A sample of sand of known weight,[a] which has been placed in a saturated surface-dry condition[b] by means of the procedure specified in Section 3 of the Tentative Method of Test for Specific Gravity and Absorption of Fine Aggregate (A.S.T.M. Designation: C 128) of the American Society for Testing Materials, shall be beaten into the mixture until the material appears to be of the desired consistency (flow 100 ± 5).
>
> ---
>
> [a] For six 2-in. cubes, 600 g. of cement and 360 ml. of water will usually give sufficient mortar. The quantity of sand used with this amount of cement may vary from 1200 g. for fine sand to 2000 g. or more for coarse sand.
>
> [b] If the absorption as determined by the Tentative Method of Test for Specific Gravity and Absorption of Fine Aggregate (A.S.T.M. Designation: C 128) of the American Society for Testing Materials is known, sand may be prepared for test by adding to a known weight of dry sand the amount of water it will absorb, and permitting the sand to stand in a covered pan for 30 min. before use.

Tentative revision, submitted August, 1938.

Section 3.—After the first sentence add three new sentences to read as follows:

> The flow table with the attached shaft shall weigh 9 ± 1 lb. The frame of the table shall be attached rigidly to a concrete pedestal which in turn is attached rigidly to the floor. The concrete pedestal shall be at least 8 in. in diameter and 25 in. in height and shall weigh at least 100 lb.

Tentative revision, submitted August, 1938.

Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 - 27):[1]

The Tentative Method of Test for Unit Weight of Aggregate (C 29 – 38 T)[2] is in effect a tentative revision of and is intended to replace when adopted the present Standard C 29 – 27.

Tentative revision, submitted August, 1938.

Standard Definitions of Terms Relating to Lime (C 51 - 28):[1]

Hydrated Lime.—Change this definition to read as follows by the addition of the italicized word and the omission of the word in brackets:

> Hydrated Lime.—A dry powder obtained by treating quicklime with water enough to satisfy its chemical [affinity] *activity* under the conditions of its hydration.

Standard Definitions of Terms Relating to Refractories (C 71 - 36):[1]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to Refractories (C 71 – 37 T)"[3] are intended to be added when adopted to the present Standard Definitions C 71 – 36.

Tentative revision, submitted June, 1936; Modified, June, 1937.

Standard Definitions for Fireclay Refractories (C 27 - 37):[4]

Under the center heading preceding Section 4, change the parenthetical subheading to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

> (Silica content less than [70] *65* per cent.)

Tentative revision, submitted June, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

[2] See p. 817.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 37, Part I, p. 790 (1937); also 1938 Book of A.S.T.M. Tentative Standards, p. 606.

[4] 1937 Supplement to Book of A.S.T.M. Standards, p. 85.

Under the center heading preceding Section 6, change the parenthetical subheading to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

(Silica content [70] *65* per cent or over.)

Tentative revision, submitted June, 1938.

Standard Definitions of Terms Relating to the Gypsum Industry (C 11 - 28):[1]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 31 T)"[2] are intended to be added when adopted to the present Standard Definitions C 11 – 28.

Tentative revision, submitted June, 1916; Modified, June, 1931.

Standard Definition of the Term Sand (C 58 - 28):[1]

The Tentative Definition of the Term Aggregate (C 58 – 28 T)[3] is intended to be included, when adopted, with the present Standard Definition C 58 – 28.

Tentative revision, submitted June, 1926; Modified, June, 1928.

Standard Specifications for Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 - 31):[1]

The Tentative Specifications for Aluminum Powder for Paints (Aluminum Bronze Powder) (D 266 – 38 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard D 266 – 31.

Tentative revision, submitted June, 1938.

Standard Specifications for Commercial Para Red (D 264 - 28):[1]

The Tentative Specifications for Reduced Para Red (D 264 – 38 T)[5] are in effect a tentative revision of and are intended to replace when adopted the present Standard D 264 – 28.

Tentative revision, submitted June, 1938.

Standard Specifications for Red Lead (D 83 - 31):[1]

The Tentative Specifications for Red Lead (D 83 – 38 T)[6] are in effect a tentative revision of and are intended to replace when adopted the present Standard D 83 – 31.

Tentative revision, submitted June, 1938.

Standard Specifications for Zinc Sulfide (D 386 - 36):[1]

Section 2.—Change Paragraph (*a*) to read as follows by the addition of the italicized words and the omission of those in brackets:

2. (*a*) Dry Pigment.—The dry pigment shall consist of zinc sulfide, within the limits [described below, without the addition of any material other than that incident to the process of manufacture] *prescribed in these specifications.*

Tentative revision, submitted June, 1937.

Standard Specifications for Normal Butyl Acetate (88 to 92 per cent Grade) (D 303 - 33):[1]

Section 1.—Change the requirement for water to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

Water . . . . miscible without turbidity [in all proportions] with *19 volumes of* 60° [Baumé] *A.P.I.* gasoline at 20 C.

Tentative revision, submitted June, 1938.

Standard Specifications for Butyl Propionate (90 to 93 per cent Grade) (D 320 - 33):[1]

Make the same change in Section 1 of these specifications as is recommended above in Specifications D 303.

Tentative revision, submitted June, 1938.

Standard Specifications for Ethyl Lactate (Synthetic) (D 321 - 33):[1]

Make the same change in Section 1 of these specifications as is recommended above in Specifications D 303.

Tentative revision, submitted June, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 835 (1931); also 1938 Book of A.S.T.M. Tentative Standards, p. 513.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 616 (1928); also 1938 Book of A.S.T.M. Tentative Standards, p. 661.

[4] See p. 821.

[5] See p. 824.

[6] See p. 827.

Tentative Revision of Standard Specifications for Zinc Oxide (A.S.T.M. Designation: D 79 – 24):[1]

Section 3.—Change Paragraph (*a*) to read as follows by the addition of the italicized words and the omission of those in brackets:

3. (*a*) The color, *tinting strength*, *brightness* and *oil absorption* [color strength], when specified, shall be equal to that of a sample mutually agreed upon by *the* buyer and *the* seller.

Revision submitted, June, 1937.

Tentative Revision of Standard Specifications for Lithopone (A.S.T.M. Designation: D 208 – 26):[1]

Section 3 (*b*).—Change the requirement for zinc oxide from its present value of "2.0 per cent max." to read "1.0 per cent max."

Revision submitted, June, 1936.

Tentative Revision of Standard Specifications for Perilla Oil, Raw or Refined (A.S.T.M. Designation: D 125 – 23):[1]

Section 1.—Change the requirement for color of perilla oil to read as follows by the addition of the italicized words:

Color.................................Not darker than a freshly prepared solution of 1.0 g. potassium dichromate in 100 cc. pure H_2SO_4 (sp. gr. 1.84), *or its equivalent in iron-cobalt solution, or in Lovibond glasses.*

Revision submitted, June, 1937.

Add to Section 3 the following requirement:

Appearance.......................................clear and transparent at 65 C.

Revision submitted, June, 1937.

Section 3 (*h*).—Change the test for determining color of perilla oil from its present form to read as follows:

(*h*) *Color.*—Prepare a fresh solution of pure potassium bichromate in pure colorless H_2SO_4 (sp. gr. 1.84). This solution should be in the proportion of 1.0 g. of potassium bichromate to 100 ml. (184.0 g.) of H_2SO_4. Place the oil and colored solution in separate thin-walled, clear glass tubes of the same diameter (1 to 2 cm.) to a depth of not less than 2.5 cm. and compare the depths of color by looking transversely through the columns of liquid by transmitted light.

The iron-cobalt liquid equivalent to the above bichromate solution may be prepared as follows: Mix 29.4 ml. of Solution No. 1 with 17.6 ml. of Solution No. 2 and 53.0 ml. of Solution No. 3. The three base solutions referred to have the following composition:

Solution No. 1	$FeCl_3 \cdot 6H_2O$	5.0 g.
	HCl (2 per cent)	1.2 g.
Solution No. 2	$CoCl_2 \cdot 6H_2O$	1.0 g.
	HCl (2 per cent)	3.0 g.
Solution No. 3	Aqueous solution of HCl (2 per cent)	

The Lovibond equivalent to the above iron-cobalt solution shall be as follows: red 17.5, yellow 120.0, and blue 0.20.

The depth of liquid shall be 10.5 mm.

Revision submitted, June, 1937.

Add the following test for appearance of perilla oil to this section as a new Paragraph (*i*):

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[1] 1936 Book of A.S T.M. Standards, Part II.

(*i*) *Appearance.*—If the oil is cloudy when cold, it shall become clear and transparent when heated at 65 C. for 5 min. Revision submitted, June, 1937.

Tentative Revision of Standard Specifications for Raw Tung Oil (A.S.T.M. Designation: D 12 - 33):[1]

Section 1.—In the table of properties and tests change the requirement for specific gravity from its present form: namely,

	MAXIMUM	MINIMUM
Specific Gravity at 15.5°/15.5° C.	0.943	0.9400

to read as follows:

	MAXIMUM	MINIMUM
Specific Gravity at 15.5/15.5 C.	0.943	0.940[a]

[a] For American grown tung oil the minimum specific gravity may be as low as 0.938.

Revision submitted, June, 1935.

Change the table in Section 1 by the addition of the following requirements for color and appearance of raw tung oil:

Color	Not darker than a freshly prepared solution of 1.0 g. potassium dichromate in 100 ml. pure H_2SO_4 (sp. gr. 1.84), or its equivalent in iron-cobalt solution, or in Lovibond glasses.
Appearance	clear and transparent at 65 C.

Revision submitted, June, 1937.

Section 3.—Add the following note at the end of Paragraph (*c*) of this section:

NOTE.—If tung oil of low acid value and pale color is desired, the maximum acid value should be reduced to 3.0, and the maximum color to 0.03 g. of dichromate per 100 ml. of H_2SO_4 (or iron-cobalt, or Lovibond equivalents). Revision submitted, June, 1937.

Change the descriptions of the heating test and the quality test described in Paragraphs (*h*) and (*i*), of Section 3 from their present form to read as follows:

(*h*) *Heating Test.*—The test tubes for the oil shall be 15 cm. by 16 mm., with a mark near the bottom to indicate 5 ml. Each tube shall be closed by a cork so perforated that a glass rod 3 mm. in diameter may be moved freely. The tubes shall each weigh 14.5 ± 2.0 g. (The purpose of this requirement is to control the wall thickness.)

Fill a 1000-ml. tall-form glass beaker (height 19 cm., diameter about 9 cm.) with cottonseed oil or other suitable oil to a height of 11 cm. Place the thermometer as shown in Fig. 1 so that the bottom will be level with the bottoms of the test tubes.

Use a nitrogen-filled, chemical thermometer, engraved stem, total length 4 to 4½ in., graduated from 210 to 310 C. in 2 C. intervals; the length between 210 and 310 C. not less than 2½ in. Thermometer glass shall be well annealed. This thermometer may be suspended in the bath by a wire or may be sealed to a glass rod as shown in Fig. 1.

When the bath temperature is 293 C. (560 F.) and very slowly rising at this point, place the tube containing 5 ml. of the oil to be tested and the tube containing 5 ml. of a control sample of known value into the large holes of the cover. Note the tim. eRemove the source of heat for about 45 sec. and then re-apply. Before 2 min. have elapsed the temperature of the bath will have fallen to 282.2 C. (540 F.), at which point it should be kept as steady as possible. When the samples have been in the bath 9 min. raise the glass rods at intervals of 15 sec. Note the time when each sample becomes firmly set. At this period the oil will be so stiff that the entire tube may be lifted by aid of the rod. As setting or jellying takes place within a few seconds of fluidity, a good end point is afforded. Remove the samples. Heat the bath again to 293 C. (560 F.), and repeat the experiment with fresh portions of the sample.

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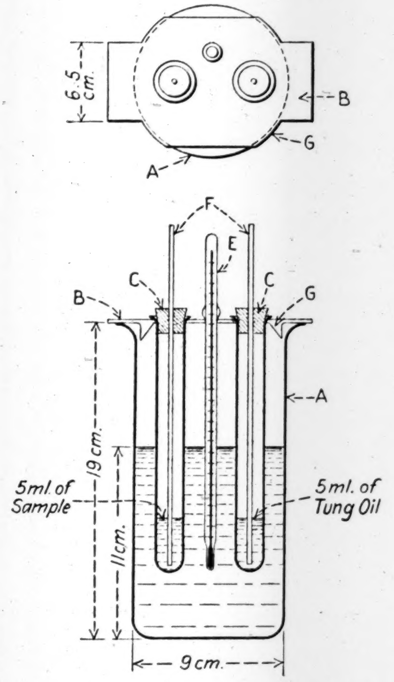
[1] 1936 Book of A.S.T.M. Standards, Part II.

No stirrer is used in the bath. A screen around the bath enables the temperature to be reached more easily. When the bath oil has become tarry and viscid, it should be renewed; otherwise heating may be irregular.



A. 1000-ml. tall-form beaker, 9 cm. in diameter by 19 cm. in height.
B. Support plate about 6.5 cm. wide, made of Monel metal, aluminum or stainless steel.
C. Corks.
D. Test tubes 15 cm. by 16 mm.
E. Thermometer, range 210 to 310 C.
F. Glass rods 3 mm. in diameter.
G. Guide to prevent cover from slipping.

FIG. 1.—Tung Oil Heating Test Apparatus (Revised, 1935).

(*i*) *Quality Test.*[a]—The apparatus required for this test consists of an ordinary vitreous enameled iron casserole having a bottom diameter of 7.5 cm. (3 in.); a wide flange tripod with a 7.5-cm. (3-in.) opening (the object of the flange is to prevent super-heating of the sides of the casserole); a total-immersion chemical thermometer, range 30 to 300 C. and 14 to 15 in. in length.

Put into the casserole 150 g. of the oil and heat so that the temperature reaches 282.2 C. (540 F.) in 4 min. ±30 sec., stirring with the thermometer. Turn down the flame and hold the heat as near 282.2 C. ± 1 C. (540 F. ± 2 F.) as possible, stirring with the thermometer, until on lifting the latter, the oil drops with a pronounced string, showing that polymerization has started. The time required after reaching 282.2 C.

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[a] Based on Worstall test.

(540 F. ± 2 F.) until the string is noted, is the time of the heat test. For pure tung oils this will not exceed 8 min. As soon as the oil strings, remove the lamp and the thermometer, and stir with a stiff spatula until the oil is solid. After stringing, a pure tung oil will require not over 40 sec. more to become solid. When solid, allow to stand just 1 min., then turn out, upside down, on clean paper and cut at once with a clean spatula.

Pure tung oil gives a gel that is dry, not adhering to the spatula when cut, that is firm, crumbling under pressure of the spatula without sticking, and the cut portions should crumble under pressure like dry bread crumbs. Adulterated tung oil gives a gel that is soft, sticky, and which will not crumble.

Revision submitted, June, 1935.

Add to Section 3 as a new Paragraph (*j*) a description of the test for determining color identical with that recommended above for inclusion in Section 3 (*h*) of Specifications D 125 – 23. At the end of this new Paragraph (*j*) add the same Note as proposed above for inclusion in Paragraph (*c*).

Add to Section 3 as a new Paragraph (*k*) a description of the test for appearance identical with that recommended above in Section 3 (*i*) of Specifications D 125 – 23.

Revision submitted, June, 1937.

Tentative Revision of Standard Methods of Sampling and Testing Shellac (A.S.T.M. Designation: D 29 – 33):[1]

Section 19.—Delete this section which describes the procedure for the determination of wax in orange, button, seed, and regular bleached shellac.

Revision submitted, June, 1936.

Tentative Revision of Standard Method of Routine Analysis of Dry Cuprous Oxide (A.S.T.M. Designation: D 283 – 36):[1]

The Tentative Method of Routine Analysis of Dry Cuprous Oxide (D 283 – 38 T)[2] is in effect a tentative revision of and is intended to replace when adopted the present Standard Method D 283 – 36.

Revision submitted, June, 1938.

Tentative Revision of Standard Specifications for Block for Granite Block Pavements (A.S.T.M. Designation: D 59 – 26):[1]

Section 3 (a).—Change to read as follows by the addition of the italicized words:

3. (*a*) The percentage of wear and the French coefficient of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Rock (A.S.T.M. Designation: D 2) of the American Society for Testing Materials, ***except that the sample shall be prepared by use of a press and the fragments shall be as uniform and as nearly cubical as practicable.***

Revision submitted, June, 1929.

Tentative Revision of Standard Specifications for Block for Recut Granite Block Pavements (A.S.T.M. Designation: D 131 – 23):[1]

Section 3 (a).—Make the same change in this section as recommended in Section 3 (*a*) of Specifications D 59 – 26 above.

Revision submitted, June, 1929.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

[2] See p. 845.

Standard Specifications for Block for Durax Granite Pavements (D 132 - 23):[1]

Section 3 (a).—Make the same change in this section as recommended in Section 3 (a) of Specifications D 59 - 26 above.

Tentative revision, submitted June, 1929.

Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 36):[1]

Section 3.—Add the following new sentence at the end of the third paragraph of this section:

If it is found impossible to meet the requirements for both flame and burning time, the requirement for burning time is the more important.

Tentative revision, submitted June, 1938.

Section 4.—Letter the present section as Paragraph *(a)* and add a new Paragraph *(b)* to read as follows:

(*b*) *Special Procedure for Light Distillate Oils Having Carbon Residues Less than 0.05 per cent, Such as No. 1 and No. 2 Fuel Oils.*—In the case of these oils, the carbon residue test shall be made on a 10 per cent residuum obtained by an adaptation of the distillation procedure in the Standard Method of Test for Distillation of Gas Oil and Similar Distillate Fuel Oils (A.S.T.M. Designation: D 158) of the American Society for Testing Materials with respect to Sections 8 (*b*) and 10, as follows:

To receive the distillate, use the 200-ml. graduate, without cleaning, used to measure the initial sample.

Maintain the condenser outlet at 32 to 40 F. (0 to 4.45 C.) throughout the distillation in the case of products having distillation end points below 600 F. (315 C.), and use the standard condenser temperatures 90 to 100 F. (32.2 to 37.8 C.) for products having end points above 600 F. (315 C.), or in those cases where waxy distillates are obtained.

Carry out the distillation at the rate prescribed until exactly 178 ml. have been collected in the graduate, then discontinue the heating and allow the condenser to drain until 180 ml. (90 per cent of the charge to the flask) has been collected in the graduate. Replace the graduate with a small Erlenmeyer flask and catch any final drainage in this flask.

To this Erlenmeyer flask add, while still warm, the residue left in the distillation flask and shake well.

The contents of the Erlenmeyer flask then represent a 10 per cent residuum from the original product. While warm enough to flow freely, pour approximately 10 g. of the residuum into the weighed crucible to be used in the carbon-residue test. After cooling, determine the weight of the sample accurately and carry out the carbon-residue test in accordance with the standard method as given in Section 3. Report the percentage of carbon residue in the residuum as "carbon residue on 10 per cent residuum."

NOTE.—It is important that a clean distillation flask be used for each test.

Tentative revision, submitted June, 1938.

Section 5.—At the end of this section add a new sentence to read as follows:

In the case of the carbon residue on 10 per cent residuum, duplicate determinations should differ by not more than 20 per cent from an average if the value is 0.10 per cent or higher. For lower values the deviations of individual determinations will be higher, increasing as the carbon residue decreases.

Tentative revision, submitted June, 1938.

Standard Method of Test for Cloud and Pour Points (D 97 - 34):[1]

New Section.—Add the following paragraph at the end of this method as a new Section 13.

13. *Reproducibility of Results.*—Individual results of the pour test on the same oil in any one laboratory may vary by 5 F. and in different laboratories by 10 F., although the average of three or more results in different laboratories should show a difference between averages no greater than 5 F. For oils tested by the special procedure described in Section 12, reproducibility of this order cannot be expected, as these oils show anomalous pour points depending on their previous thermal history.[a]

[a] It is a recognized property of these oils that the temperature to which they have been subjected before testing influences their pour points. Although the lower pour points as determined by the special procedure will show approximately the reproducibility given above, yet the upper pour points will show greater variations depending on the previous thermal history of the oils. Further information on this subject is contained in *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, pp. 468 to 470 (1931), and Vol. 32, Part I, pp. 402 to 405 (1932).

Tentative revision, submitted June, 1938.

Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 - 37):[1]

Section 6 (b) and (c).—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

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[1] 1936 Book of A.S.T.M. Standards, Part II.

(*b*) *Crude petroleum or a product thereof* [A product] with *an* initial boiling point below 250 F. (121.1 C.) and an A.P.I. gravity below 70 *deg.* shall be cooled in the original closed container to a temperature of 65 F. (18.3 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum or a product thereof* [A product] having an A.P.I. gravity of 70 *deg.* or greater shall be cooled in the original closed container to a temperature of 35 F. (1.7 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum having an initial boiling point below 250 F. (121.1 C.) which has too high a pour point or is too viscous at 65 F. (18.3 C.) to permit an accurate hydrometer reading at 65 F. (18.3 C.) or below should be heated to the minimum temperature which will give sufficient fluidity to permit an accurate hydrometer reading.*

(*c*) The thermometer, hydrometer, and hydrometer cylinder shall be at approximately the same temperature as the *sample* [product] to be tested. Precaution shall be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing nonvolatile and nonviscous *samples* [oils] by choosing a temperature of test only slightly different from the room temperature. When volatile [products] *samples (those having initial boiling points below 250 F. (121.1 C.) and also those having A.P.I. gravities greater than 70 deg.)* are cooled, or viscous [products] *samples are* heated, the test cylinder shall be placed in a bath maintained at the *necessary* [a constant desired] temperature during the time of test. *In determining the gravity of any crude petroleum or product, the temperature of the surrounding medium should not differ from the temperature of the sample by more than 5 F. (2.8 C.).*

Tentative revision, submitted June, 1938.

Standard Method of Test for Ductility of Bituminous Materials (D 113 - 35):[2]

Section 5.—Change the second sentence to read as follows by the addition of the italicized words:

It shall then be strained through a No. 50 sieve *conforming to the requirements prescribed in the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials* and, after a thorough stirring, poured into the mold.

Change the last sentence to read as follows by the addition of the italicized words:

It shall be left to cool to room temperature *for a period of from 30 to 40 min.*, and then placed in the water bath maintained at the specified temperature of test for 30 min., after which the excess bitumen shall be cut off by means of a hot straight-edged putty knife or spatula so that the mold shall be just level full.

Change the Note following this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

NOTE.—When paving asphalt cements are being tested, the oil bath shall be maintained at a temperature of from [125 to 150 C. (257 to 302 F.)] *150 to 160 C. (302 to 320 F.).*

Tentative revision, submitted June, 1938.

Section 6.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

6. The brass plate and mold, with briquet, shall then be placed in the water bath and kept at the specified temperature for [at least 1½ hours] *a period of from 85 to 95 min.*, when the briquet shall be removed from the plate, the side pieces detached, and the briquet tested immediately.

Tentative revision, submitted June, 1938.

Section 7.—In the first and last sentences of this section change the words "ductility machine" to read "testing machine."

Tentative revision, submitted June, 1938.

Standard Methods of Chemical Analysis of Rubber Products (D 297 - 38):[3]

Section 31.—Change the formula for calculating the percentage of rubber by volume appearing in this section, to read as follows by the addition of the italicized figures and the omission of the figures in brackets:

$$\text{Rubber by volume, per cent} = \frac{R \times G}{[0.94]\ \mathit{0.92}}$$

where:

R = the percentage of rubber as compounded,

G = the specific gravity of the compound,

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 121.

[2] 1936 Book of A.S.T.M. Standards, Part II.

[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 202.

[0.94] *0.92* = the assumed average specific gravity of rubber.

Tentative revision, submitted August, 1938.

Standard Method of Test for Hardness of Rubber (D 314 - 34):[1]

Section 10 (a).—Change the first sentence of this paragraph to read as follows by the addition of the italicized words and the omission of those in brackets:

> The pressure foot [and indentor] shall be lowered *first* until contact is made with the test specimen. *The indentor shall then be lowered.*

Tentative revision, submitted August, 1938.

Standard Specifications for Textile Testing Machines (D 76 - 37):[2]

Section 2 (d).—Change this section from its present form: namely,

> (*d*) Machines of Type *A* shall be calibrated throughout the loading range of a 9 to 45-deg. swing of the pendulum from the vertical with weights of accurate amounts applied in an ascending order and under machine conditions similar to those specified for the test under consideration.

to read as follows:

> (*d*) Vertical machines of Type *A* shall be calibrated throughout the loading range of a 9 to 45-deg. swing of the pendulum from the vertical position using a series of weights of known amount applied in an ascending order. The weights shall be fastened to the upper clamp in any convenient manner and suspended freely, thereby causing the pendulum to swing from the vertical position. The equilibrium position of the pendulum for each weight shall be determined by disengaging the pawls, bringing the pendulum slightly below its equilibrium position, engaging the pawls, and then releasing the pendulum and allowing it to swing up to the equilibrium position with the pawls engaged. The average of several readings for each weight shall be used to determine the dial and chart errors.

Tentative revision, submitted June, 1938.

New Sections.—Add as new Sections 8 and 9 the following requirements for testers for determining bursting strength:

Bursting Testers

8. *Attachment for Type A Machines.*—The attachment for making the bursting test on a Type *A* machine shall be of such design that the sample shall be securely held by a ring-clamp mechanism not less than $1\frac{3}{4}$ in. in internal diameter and be drawn down against a 1-in. polished steel ball until a burst is produced. The capacity of the machine shall conform to the requirements of Section 2 (*b*).

9. *Diaphragm Bursting Testers:* (*a*) The tester shall be driven at a constant rate of speed which insures a uniform displacement of the pressure medium of $6 \pm \frac{1}{4}$ cu. in. per min. Means shall be provided for stopping, at the instant of rupture of the specimen, any further application of the loading pressure, and for holding unchanged the contents of the pressure chamber until the gross bursting pressure and tare diaphragm pressure, simultaneously indicated on the gage, shall have been recorded.

NOTE.—It is recommended that the difference between the gross bursting pressure and the tare diaphragm pressure be reported as the bursting strength of the material.

(*b*) The pressure gage shall be of the Bourdon tube, maximum hand type, having a dial at least $4\frac{1}{2}$ in. in diameter and accurate throughout the entire range of its scale to within a plus or minus value equal to 0.25 per cent of its maximum capacity. When the gage is calibrated, it shall be mounted in the same relative position as on the bursting tester. If calibrated with a dead-weight tester, the weights shall be spun slowly to insure free action of the piston.

(*c*) The surfaces between which the specimen is clamped shall be smooth, flat, and metallic, and any edge which might cause a cutting action shall be rounded to a radius of not over $\frac{1}{64}$ in. The ring-clamp shall have a circular aperture of 1.200 ± 0.001 in. This aperture shall be co-axial with the opening of the diaphragm plate.

(*d*) Provision shall be made for applying to the specimen, before clamping, an initial tension which shall be uniform in all directions.

Tentative revision, submitted June, 1938.

Standard General Methods of Testing and Tolerances for Cotton Yarns and Threads (D 180 - 37):[1]

Section 2 (d).—Change this section to read as follows by the omission of the figure in brackets and the addition of the italicized figure:

> (*d*) *Standard Regain.*—The standard regain for cotton yarn or thread shall be [7] *7.5* per cent of the moisture-free weight.

Tentative revision, submitted June, 1938.

New Section.—Add under tolerances as a new Section 6 the following requirement for "appearance" of cotton yarns words and figures and the omission of those in brackets:

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[1] 1936 Book of A.S.T.M. Standards, Part II.

[2] 1937 Supplement to Book of A.S.T.M. Standards, p. 241.

(*b*) *Crude petroleum or a product thereof* [A product] with *an* initial boiling point below 250 F. (121.1 C.) and an A.P.I. gravity below 70 *deg.* shall be cooled in the original closed container to a temperature of 65 F. (18.3 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum or a product thereof* [A product] having an A.P.I. gravity of 70 *deg.* or greater shall be cooled in the original closed container to a temperature of 35 F. (1.7 C.) or lower before pouring into the hydrometer cylinder. *Crude petroleum having an initial boiling point below 250 F. (121.1 C.) which has too high a pour point or is too viscous at 65 F. (18.3 C.) to permit an accurate hydrometer reading at 65 F. (18.3 C.) or below should be heated to the minimum temperature which will give sufficient fluidity to permit an accurate hydrometer reading.*

(*c*) The thermometer, hydrometer, and hydrometer cylinder shall be at approximately the same temperature as the *sample* [product] to be tested. Precaution shall be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing nonvolatile and nonviscous *samples* [oils] by choosing a temperature of test only slightly different from the room temperature. When volatile [products] *samples (those having initial boiling points below 250 F. (121.1 C.) and also those having A.P.I. gravities greater than 70 deg.)* are cooled, or viscous [products] *samples are* heated, the test cylinder shall be placed in a bath maintained at the *necessary* [a constant desired] temperature during the time of test. *In determining the gravity of any crude petroleum or product, the temperature of the surrounding medium should not differ from the temperature of the sample by more than 5 F. (2.8 C.).*

Tentative revision, submitted June, 1938.

Standard Method of Test for Ductility of Bituminous Materials (D 113 - 35):[2]

Section 5.—Change the second sentence to read as follows by the addition of the italicized words:

It shall then be strained through a No. 50 sieve *conforming to the requirements prescribed in the Tentative Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials* and, after a thorough stirring, poured into the mold.

Change the last sentence to read as follows by the addition of the italicized words:

It shall be left to cool to room temperature *for a period of from 30 to 40 min.*, and then placed in the water bath maintained at the specified temperature of test for 30 min., after which the excess bitumen shall be cut off by means of a hot straight-edged putty knife or spatula so that the mold shall be just level full.

Change the Note following this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

NOTE.—When paving asphalt cements are being tested, the oil bath shall be maintained at a temperature of from [125 to 150 C. (257 to 302 F.)] *150 to 160 C. (302 to 320 F.).*

Tentative revision, submitted June, 1938.

Section 6.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

6. The brass plate and mold, with briquet, shall then be placed in the water bath and kept at the specified temperature for [at least $1\frac{1}{2}$ hours] *a period of from 85 to 95 min.*, when the briquet shall be removed from the plate, the side pieces detached, and the briquet tested immediately.

Tentative revision, submitted June, 1938.

Section 7.—In the first and last sentences of this section change the words "ductility machine" to read "testing machine."

Tentative revision, submitted June, 1938.

Standard Methods of Chemical Analysis of Rubber Products (D 297 - 38):[3]

Section 31.—Change the formula for calculating the percentage of rubber by volume appearing in this section, to read as follows by the addition of the italicized figures and the omission of the figures in brackets:

$$\text{Rubber by volume, per cent} = \frac{R \times G}{[0.94]\ \mathit{0.92}}$$

where:

R = the percentage of rubber as compounded,
G = the specific gravity of the compound,

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 121.

[2] 1936 Book of A.S.T.M. Standards, Part II.

[3] 1938 Supplement to Book of A.S.T.M. Standards, p. 202.

[0.94] *0.92* = the assumed average specific gravity of rubber.

Tentative revision, submitted August, 1938.

Standard Method of Test for Hardness of Rubber (D 314 - 34):[1]

Section 10 (a).—Change the first sentence of this paragraph to read as follows by the addition of the italicized words and the omission of those in brackets:

> The pressure foot [and indentor] shall be lowered *first* until contact is made with the test specimen. *The indentor shall then be lowered.*

Tentative revision, submitted August, 1938.

Standard Specifications for Textile Testing Machines (D 76 - 37):[2]

Section 2 (d).—Change this section from its present form: namely,

> (*d*) Machines of Type *A* shall be calibrated throughout the loading range of a 9 to 45-deg. swing of the pendulum from the vertical with weights of accurate amounts applied in an ascending order and under machine conditions similar to those specified for the test under consideration.

to read as follows:

> (*d*) Vertical machines of Type *A* shall be calibrated throughout the loading range of a 9 to 45-deg. swing of the pendulum from the vertical position using a series of weights of known amount applied in an ascending order. The weights shall be fastened to the upper clamp in any convenient manner and suspended freely, thereby causing the pendulum to swing from the vertical position. The equilibrium position of the pendulum for each weight shall be determined by disengaging the pawls, bringing the pendulum slightly below its equilibrium position, engaging the pawls, and then releasing the pendulum and allowing it to swing up to the equilibrium position with the pawls engaged. The average of several readings for each weight shall be used to determine the dial and chart errors.

Tentative revision, submitted June, 1938.

New Sections.—Add as new Sections 8 and 9 the following requirements for testers for determining bursting strength:

Bursting Testers

8. *Attachment for Type A Machines.*—The attachment for making the bursting test on a Type *A* machine shall be of such design that the sample shall be securely held by a ring-clamp mechanism not less than $1\frac{3}{4}$ in. in internal diameter and be drawn down against a 1-in. polished steel ball until a burst is produced. The capacity of the machine shall conform to the requirements of Section 2 (*b*).

9. *Diaphragm Bursting Testers:* (*a*) The tester shall be driven at a constant rate of speed which insures a uniform displacement of the pressure medium of $6 \pm \frac{1}{4}$ cu. in. per min. Means shall be provided for stopping, at the instant of rupture of the specimen, any further application of the loading pressure, and for holding unchanged the contents of the pressure chamber until the gross bursting pressure and tare diaphragm pressure, simultaneously indicated on the gage, shall have been recorded.

NOTE.—It is recommended that the difference between the gross bursting pressure and the tare diaphragm pressure be reported as the bursting strength of the material.

(*b*) The pressure gage shall be of the Bourdon tube, maximum hand type, having a dial at least $4\frac{1}{2}$ in. in diameter and accurate throughout the entire range of its scale to within a plus or minus value equal to 0.25 per cent of its maximum capacity. When the gage is calibrated, it shall be mounted in the same relative position as on the bursting tester. If calibrated with a dead-weight tester, the weights shall be spun slowly to insure free action of the piston.

(*c*) The surfaces between which the specimen is clamped shall be smooth, flat, and metallic, and any edge which might cause a cutting action shall be rounded to a radius of not over $\frac{1}{64}$ in. The ring-clamp shall have a circular aperture of 1.200 ± 0.001 in. This aperture shall be co-axial with the opening of the diaphragm plate.

(*d*) Provision shall be made for applying to the specimen, before clamping, an initial tension which shall be uniform in all directions.

Tentative revision, submitted June, 1938.

Standard General Methods of Testing and Tolerances for Cotton Yarns and Threads (D 180 - 37):[1]

Section 2 (d).—Change this section to read as follows by the omission of the figure in brackets and the addition of the italicized figure:

> (*d*) *Standard Regain.*—The standard regain for cotton yarn or thread shall be [7] *7.5* per cent of the moisture-free weight.

Tentative revision, submitted June, 1938.

New Section.—Add under tolerances as a new Section 6 the following requirement for "appearance" of cotton yarns or threads, renumbering the present sections accordingly:

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[1] 1936 Book of A.S.T.M. Standards, Part II.

[2] 1937 Supplement to Book of A.S.T.M. Standards, p. 241.

6. *Appearance.*—The appearance of the yarn or thread shall be at least equal to that of the grade specified.

Tentative revision, submitted June, 1938.

Section 9 (c).—To conform with the revision in Section 2, recommended above, change the regain for cotton yarns as given in this section, from "7 per cent" to read "7.5 per cent"; also, in the numerator of the two formulas, change the figure "142" to read "145"; and in the second formula, change the corrected tensile strength value of "131 lb." to read "134 lb."

Tentative revision, submitted June, 1938.

Section 11 (f).—To conform with the revision in Section 2, recommended above, change the regain for cotton yarns as given in this section, from "7 per cent" to read "7.5 per cent"; also, in the denominator of the formula in this section, change the figure "107" to read "107.5."

Tentative revision, submitted June, 1938.

New Section.—Add under methods of testing as a new Section 14 the following test for appearance of cotton yarns or threads:

14. *Appearance: (a) Grades.*—Photographic standards have been established in Grades *A*, *B*, *C*, and *D*, where *A* is the highest grade and the others are progressively lower. These grades apply to several groups of yarn numbers for each of which there is a separate set of standards. The grouping of yarn numbers is as follows:

3.0 to 7.0
7.0 to 16.5
16.5 to 32.0
32.0 to 65.0
65.0 to 125.0

(*b*) *Test.*—A sample of the yarn under test shall be wound upon a black board of designated size with a designated traverse and compared with a photographic standard (Note).

(*c*) *Number of Tests.*—Five tests shall be made on each case, bale, chain ball, or beam warp. If 80 per cent of the results meet the specified grade and the remaining 20 per cent do not fall below the next lower grade, the yarn shall be considered to be of the grade specified.

NOTE.—A complete set of photographic standards for each group of yarns, together with detailed information regarding the size of board and traverse, may be obtained at nominal cost from Mr. M. E. Campbell, U. S. Department of Agriculture, Division of Cotton Marketing, Washington, D. C.

Tentative revision, submitted June, 1938.

Standard Methods of Testing and Tolerances for Cotton Sewing Threads (D 204 - 36):[1]

Section 11.—Change the first sentence of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

[Three tests for] *Four methods for the determination of* yardage are given below in their order of preference:

Add as a new Paragraph (*a*) under this section the following method for determining yardage of thread in a package, relettering the present paragraphs accordingly:

(*a*) The length of thread in a package shall be determined by a wheel or roll which measures the length by direct contact with the thread. The thread shall be held continuously under a definite tension in accordance with that prescribed in Section 12 (*c*) of the Standard D 180. The measuring unit shall be driven in such a manner that the slip on the thread is less than 0.1 per cent.

Tentative revision, submitted June, 1938.

Standard Specifications and Methods of Test for Cotton Goods for Rubber and Pyroxylin Coating (D 334 - 34):[1]

Section 4.—Change the total allowable percentages of sizing and natural oils and waxes for sateens and broken twills, specified in this section, to read as follows, by the addition of the italicized percentages and the omission of those in brackets:

Sheetings	8.5 per cent
Drill	11 per cent
Sateens	[10.25] *11* per cent
Broken Twills	[8.15] *11* per cent

Tentative revision, submitted June, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

Section 14.—Delete the present section and substitute the following preferred and alternate methods for determining the amount of sizing as Sections 14 and 15 respectively, renumbering the remaining sections accordingly:

14. *Sizing, Preferred Method.*—Tests to determine the amount of sizing and other non-fibrous materials shall be made in accordance with the following procedure:

(*a*) A glass weighing bottle of approximately 100-ml. capacity fitted with a ground-glass cover shall be heated in a ventilated drying oven at 105 to 110 C. as follows: Place the bottle and cover separately in the oven and after drying for 1 hr. or more, remove from the oven and place them in a desiccator and allow to cool to room temperature. Then place the cover on the bottle, and weigh. The drying, cooling, and weighing shall be repeated until the weight is constant to within plus or minus 0.005 g. This is the "weight of the weighing bottle."

(*b*) A specimen weighing approximately 10 g. shall be taken for analysis. Particular care shall be taken to prevent the loss of fibers during the treatment. The specimen shall be placed in the weighing bottle and dried in accordance with the procedure specified in Paragraph (*a*). The drying, cooling, and weighing shall be repeated until the weight is constant to within plus or minus 0.005 g. By subtracting the "weight of the weighing bottle" (Paragraph (*a*)) from this weight, the weight of dry specimen, A, is obtained.

(*c*) *Procedure.*—An approximately 0.1 N HCl solution shall be prepared by diluting 8.6 ml. of HCl (sp. gr. 1.19) to 1 liter with distilled water. In a 400-ml. beaker, 200 ml. of this solution shall be brought to boiling and the specimen shall then be immersed in the boiling solution, the beaker covered with a watch glass to minimize loss in volume, and the boiling continued for 30 min. Each specimen shall be treated in a separate beaker. The contents of the beaker shall be poured onto a fine sieve (No. 12 silk bolting cloth) and washed with running water with an occasional squeezing of the specimen with the finger tips. After draining off the water, the specimen shall be squeezed as dry as possible with the fingers, wiped around the sieve to pick up loose fibers and immersed in a dilute solution of ammonium hydroxide (10 ml. of NH_4OH (28 to 29 per cent NH_3) diluted to 1 liter with distilled water). The contents of the beaker shall then be poured on the bolting cloth sieve and washed as directed above. Finally, the specimen shall be squeezed as dry as possible with the fingers, wiped around the sieve to pick up loose fibers, and placed in the weighing bottle and dried to constant weight in accordance with Paragraph (*b*). By subtracting the "weight of the weighing bottle" (Paragraph (*a*)) from this weight, the weight of the dry cotton cellulose, B, is obtained.

(*d*) *Calculation.*—The total amount of non-fibrous constituents present shall be calculated from the following formula:

$$\text{Total sizing, finishing and other non-fibrous materials (dry basis), per cent} = \frac{A - B}{A} \times 100$$

where A = the weight of the dry specimen (Paragraph (*b*)), and

B = the weight of the dry cotton cellulose (Paragraph (*c*)).

NOTE.—The result obtained by this method includes not only the starch, filling and finishing materials added during manufacturing, but also some of the waxes and other non-cellulose natural constituents of raw cotton. The natural impurities and the amounts, removed by this treatment vary with the grade, source, and previous treatment of the cotton. When it is desired to determine the actual amount of sizing or other added substance, the actual loss due to removal of natural constituents of the cotton should be determined on the unsized cotton yarn used in making the fabric. If the unsized yarn is not available, then an allowance of 4.25 per cent may be made as the amount of natural non-cellulose materials removed.

15. (*a*) *Sizing, Alternate Method.*—A specimen weighing approximately 10 g. shall be taken for analysis. The dry weight of the specimen, weight A, shall be determined in accordance with the procedure in Section 14 (*a*) and (*b*).

(*b*) *Procedure.*—The specimen shall be treated in accordance with the procedure in Section 14 (*c*) except that a 0.05 N HCl solution (4.3 ml. HCl (sp. gr. 1.19) diluted to 1 liter with distilled water) shall be used; and, after the treatment with the HCl solution and rinsing with water, the specimen shall be immersed in 200 ml. of a 0.18 N Na_2CO_3 solution (9.6 g. Na_2CO_3, reagent grade, per liter of solution), previously brought to the boiling point, and boiled gently for 30 min. The weight of the dried residue from this treatment is weight B.

(*c*) *Calculation.*—The total amount of non-fibrous constituents present shall be calculated from the following formula:

$$\text{Total sizing, finishing and other non-fibrous materials (dry basis), per cent} = \frac{A - B}{A} \times 100$$

where A = the weight of the dry specimen (Paragraph (*a*)), and

B = the weight of the dry cotton cellulose (Paragraph (*b*)).

NOTE.—The Note under Section 14 applies to this method except that an allowance of 5.75 per cent can be made as the amount of natural non-cellulose materials removed.

Tentative revision, submitted June, 1938.

Tentative Revision of Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39 – 38):[1]

Section 11.—Change this section from its present form: namely,

11. *Raveled Strip Method.*—This test shall be made in accordance with the directions for the grab method (Section 10) with the following exceptions: The specimens shall be $1\frac{1}{4}$ in. in width if there are 50 or more yarns per inch, and $1\frac{1}{2}$ in. in width if there are less than 50 yarns per inch. Each specimen shall be raveled to 1 in. in width by taking from each side approximately the same number of yarns. The clamps used on the testing machine shall have faces measuring 1 by $1\frac{1}{2}$ in. or more, the longer dimension being perpendicular to the direction of application of the load.

to read as follows:

11. *Raveled Strip Method.*—This test shall be made in accordance with the directions for the grab method (Section 10) with the following exceptions: This method is applicable only to fabrics containing 50 or more yarns per inch. Each specimen shall be $1\frac{1}{4}$ in. in width and shall be raveled to 1 in. in width by taking from each side approximately the same number of yarns. The clamps used on the testing machine shall have faces measuring 1 by $1\frac{1}{2}$ in. or more, the longer dimension being perpendicular to the direction of application of the load. Revision submitted, June, 1937.

New Sections.—Add the following paragraphs at the end of these methods as new Sections 16 and 17:

16. *Twist, Warp and Filling Yarns:* (*a*) *Test Specimens.*—Specimens of the fabric shall measure at least 30 in. in the warp direction for the determination of the warp twist, and at least 30 in. in the filling direction, or the full width of the fabric, for the determination of the filling twist. In all operations care must be exercised to avoid any change in the twist of the yarn to be tested. The yarns may be removed from the fabric in the following manner:

Holding the yarn to be tested at one end, remove it from the fabric for a distance in approximately 10 in. (cutting the cross yarn, if necessary) and grip it at this point of one clamp of the twist tester. Remove the yarn for an additional 10 in., straighten it by applying just sufficient tension to remove the crimp (Section 8) and then grip it in the other clamp of the twist tester. The distance between clamps shall be 10 in.

(*b*) *Procedure.*—The twist of the specimen prepared as directed in Paragraph (*a*) shall be determined by one of the following procedures of the American Society for Testing Materials:

Cotton Yarn.—Section 12 of the Standard General Methods of Testing and Tolerances for Cotton Yarns and Threads (A.S.T.M. Designation: D 180).

Woolen Yarn.—Section 21 of the Standard Methods of Testing and Tolerances for Woolen Yarns (A.S.T.M. Designation: D 403).

Worsted Yarn.—Section 21 of the Standard Methods of Testing and Tolerances for Worsted Yarns (A.S.T.M. Designation: D 404).

(*c*) *Number of Tests.*—One twist test on each of ten or more different warp yarns shall be made and the average of these ten or more tests shall be the average twist of the warp yarns. One twist test on each of ten or more different filling yarns, taken from locations in the fabric as far apart as practicable, shall be made and the average of these ten or more tests shall be the average twist of the filling yarn.

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[1] 1938 Supplement to Book of A.S.T.M. Standards p. 220.

17. *Bow.*—The fabric shall be laid out smooth on a horizontal surface without tension. The position of a filling yarn in the fabric shall be marked with a line drawn on the fabric across its full width, or by other suitable means. (Marking is not necessary when distinctive colored picks are woven into the fabric at regular intervals.) A straight edge shall be placed across the fabric between the ends of this line at the edges of the fabric. The greatest distance between the line and the straight edge, measured parallel to the edges of the fabric, and the width of the fabric along the straight edge shall be measured. Similar measurements shall be made in at least three different places along a roll or piece, preferably at points 10 yd. from each end and in the center. The bow shall be expressed as a percentage of the width of the fabric and shall be the average for the three or more sets of measurements as calculated from the following formula:

$$\text{Bow, per cent} = \frac{d}{w} \times 100$$

where d = the greatest distance in inches between the marked filling yarn and the straight edge, and

w = the width of the fabric in inches.

Revision submitted, June, 1937.

Tentative Revision of Standard Methods of Testing Electrical Porcelain (A.S.T.M. Designation: D 116 – 34):[1]

Section 1.—Change this section and the Note from their present form: namely,

1. These methods are intended to apply to porcelain and other vitrified ceramic materials used in the manufacture of electrical insulating parts.

NOTE.—Tests on porcelain are made on unglazed specimens since it is desired to determine the strength of the porcelain structure only. Tests have indicated, however, that the glaze may have an effect on the mechanical strength. In some cases the values obtained are higher and in other cases lower than obtained on unglazed specimens.

to read as follows:

1. These methods outline procedures for making the various tests described when they are required for an investigation or examination of porcelain or similar vitrified ceramic materials used as electrical insulating mediums. They are not to be interpreted as forming test specifications for complete insulators.

NOTE.—The glaze on a porcelain object may affect certain properties of the material depending not only upon its presence but also upon its thickness and composition. While the test methods have been written with the intent of applying to unglazed specimens, they are equally suitable for glazed specimens. The report of test should in all cases indicate whether the specimens are glazed or unglazed.

Revision submitted, June, 1937.

Tentative Revision of Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117 – 36):[1]

New Section.—Add the following as new Section 10, renumbering the remaining sections accordingly:

10. *Color.*—The test to determine color shall be made in accordance with the Tentative Method of Test for Color of Lubricating Oils by Means of A.S.T.M. Union Colorimeter (A.S.T.M. Designation: D 155 – 34 T) of the American Society for Testing Materials.

Revision submitted, June, 1935.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 - 37):[1]

Section 18.—Replace this section by new Sections 18 to 24, to read as follows:

18. *Dielectric Strength Test.*—Except as specified below in Sections 19 to 24, the dielectric strength shall be determined in accordance with the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 - 38 T) of the American Society for Testing Materials.[2]

19. *Electrodes.*—The test electrodes shall consist of flat disks or cylinders 1 in. in diameter, with edges rounded to a radius of $\frac{1}{8}$ in.

20. *Test Specimens.*—The test specimen shall be molded in the form of a disk 4 in. (10.16 cm.) in diameter which should be $\frac{1}{8}$ in. (${}_1{}^3{}_8$ mm.) in thickness for hot-molded materials and $\frac{1}{4}$ in. (6.35 mm.) in thickness for cold-molded materials.

NOTE.—To permit the use of one mold for all molding compounds the following variations in dimensions of the test specimen will be permissible:

For hot-molded compounds...	± 5 per cent
For cold-molded compounds..	± 10 per cent

21. *Conditioning (a).*—Five specimens shall be tested as received at 25 C. (77 F.)

(*b*) Where the test materials are to be used at other than room temperature, their dielectric strength characteristic shall be determined over the operating range of temperature. Specimens shall be exposed to each test temperature in a suitable temperature-control chamber for at least 30 min. prior to test.

(*c*) Three specimens shall be punctured after they have had the rim immersed in melted parraffin for a depth of 1 in. (25.4 mm.) and have been entirely immersed in water for 48 hr. at 25 C. (77 F.). The surface of the specimens shall be wiped-off with a dry cloth to remove all trace of excessive surface moisture and the puncture test made immediately.

22. *Surrounding Medium.*—It is recommended that all tests on hot-molded materials be made under oil, and tests on cold-molded materials in air. Where arc-over is experienced on specimens tested in air, the specimens shall be tested under oil.

23. *Procedure (a).*—Tests may be made by either the short-time method or the step-by-step method.

(*b*) In the short-time test, voltage shall be increased at the rate of 1000 v. per sec.

(*c*) In the step-by-step test, the voltage shall be increased in increments as indicated in the following table, the voltage being held at each step for 1 min.:

BREAKDOWN VOLTAGE BY SHORT-TIME METHOD	INCREMENT OF INCREASE OF TEST VOLTAGE
25 kv. or less..................	1.0 kv.
Over 25 to 50 kv., incl..........	2.0 kv.
Over 25 to 100 kv., incl........	5.0 kv.
Over 100 kv.................	10.0 kv.

24 *Number of Tests.*—Except as specified in Section 16 (*c*), at least five tests, shall be made at each test temperature in the short-time method, and at least three tests in the step-by-step method. Where the range of test temperature is considerable, tests should be made at not less than four temperatures, so that a curve of dielectric strength against temperature may be plotted.

Tentative revision, submitted June, 1938.

Standard Methods of Testing Pasted Mica Used in Electrical Insulation (D 352 - 36):[2]

Section 9 (d).—Change to read as follows by the addition of the italicized word:

(*d*) The specimen with clamp shall then be transferred as quickly as possible to the hydraulic press and a *minimum* pressure of 4400 lb. per sq. in. on the surface of the specimen applied immediately and maintained for 30 min.

Tentative revision, submitted June, 1938.

Section 21.—Replace this section by new Sections 21 and 22 to read as follows, renumbering the subsequent section accordingly:

21. *Dielectric Strength.*—Except as specified below in Section 22 the dielectric strength shall be determined in accordance with the Tentative Methods of Test for Dielectric Strength of Insulating Materials, at Commercial Power Frequencies (A.S.T.M. Designation: D 149 - 38 T) of the American Society for Testing Materials.

22. *Procedure.*—(*a*) Tests shall be made by either the short-time method or the step-by-step method.

(*b*) In tests made by the short-time method, voltage shall be increased at the rate of 0.5 kv. per sec.

(*c*) In tests made by the step-by-step method, each step shall be of 1-min. duration. An initial voltage in the short-time test, shall be adjusted as shown in the following table:

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[1] 1937 Supplement to Book of A.S.T.M. Standards.

[2] 1936 Book of A.S.T.M. Standards, Part II.

BREAKDOWN VOLTAGE BY SHORT-TIME METHOD	ADJUST 50 PER CENT OF BREAKDOWN VOLTAGE TO THE NEAREST	INCREMENT OF INCREASE OF TEST VOLTAGE
25 kv. or less.....	1.0 kv.	1.0 kv.
Over 25 to 50 kv., incl............	2.0 kv.	2.0 kv.
Over 50 to 100 kv., incl............	5.0 kv.	5.0 kv.
Over 100 kv.......	10.0 kv.	10.0 kv.

The voltage shall then be increased in equal increments as stated in the above table. The change from each step to the next higher shall be made as rapidly as possible, and the time to change included in the succeeding test interval.

Tentative revision, submitted June, 1938.

Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 - 37):[1]

Section 1.—Change the quantity of the laboratory sample prescribed in Paragraphs (*e*) and (*g*) of this section from "10 lb." to read "15 lb."

Tentative revision, submitted June, 1937.

Section 2 (*f*).—Change this section from its present form: namely,

> (*f*) *Large Riffle Sampler.*—Same as in Section 1 (*g*) for reducing coke passing the 4760-micron (No. 4) sieve to 10 lb. (see Fig. 2(*a*)).

to read as follows:

> (*f*) *Large Riffle Sampler.*—The same as in Section 1 (*g*) (see Fig. 2 (*a*)).

Tentative revision, submitted June, 1937.

Section 3 (*a*).—Change the first sentence in this section from its present form: namely,

> If the sample is coarser than will pass completely a 4760-micron (No. 4) sieve and larger in amount than 10 lb., quickly crush it with the jaw crusher to pass a 4760-micron (No. 4) sieve and reduce it on the larger riffle sampler to 10 lb.;[a] then crush it at once to pass an 840-micron (No. 20) sieve by passing through rolls or an enclosed grinder, and take, without sieving, a 50-g. total moisture sample, immediately after the material has passed through the crushing apparatus.
>
> ---
>
> [a] If the sample is crushed to pass a 3360-micron (No. 6) sieve it may be reduced to 5 lb.

to read as follows:

> The sample which has been collected and reduced in accordance with the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21) of the American Society for Testing Materials, shall be crushed[a] to pass an 840-micron (No. 20) sieve by passing through rolls or an enclosed grinder and a 50-g. total moisture sample taken, without sieving, immediately after the material has passed through the crushing apparatus.
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> ---
>
> [a] Samples crushed to pass a 4760-micron (No. 4) sieve prepared in accordance with the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21) of the American Society for Testing Materials[2] may be crushed to pass a 2380-micron (No. 8) sieve and reduced to not less than $1\frac{3}{4}$ lb. in accordance with Section 7 (*d*) of Standard Method D 21.

Tentative revision, submitted June, 1937.

Section 5 (*c*).—Insert a footnote reference "a" after the word "sample" in the first sentence of this section, this footnote to read the same as footnote "a" given above in Section 3 (*a*).

Tentative revision, submitted June, 1937.

Sections 27 to 31.—Change the description of the procedure for the determination of the fusibility of ash as given in Sections 27 to 31 from its present form to read as follows:

> 27. APPARATUS: (*a*) *Furnace.*—Any gas or electric furnace meeting the following requirements may be used:
>
> (*1*) It shall maintain a zone of uniform temperature in which to heat the ash cones,
>
> (*2*) It shall maintain a reducing atmosphere surrounding the ash cones during heating in which the ratio by volume of reducing gases to oxidizing gases is as specified in Section 30,
>
> (*3*) It shall be capable of regulation so that the rate of temperature rise shall be not less than 5 and not more than 10 deg. Cent. per min., and
>
> (*4*) It shall provide means of observing the ash cones during heating.
>
> NOTE.—Commercial gas-fired furnaces which meet these requirements are the coal-ash fusion furnace of the Denver Fire Clay Co.,[2] the No. 3 Melter's Furnace of the American Gas Furnace Co.[2] modified to provide an observation hole in the side, and the Barrett coal-ash fusion furnace of the Burrell Technical Supply Co.[3]

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[1] 1937 Supplement to Book of A.S.T.M. Standards, p. 153.

[2] For detailed information concerning operation of the coal-ash fusion furnace of the Denver Fire Clay Co. and the No. 3 Melter's Furnace of the American Gas Furnace Co., see 1937 Supplement to Book of A.S.T.M. Standards, pp. 174 to 177.

[3] For information concerning the Barrett coal-ash fusion furnace see E. P. Barrett, "A Furnace for the Measurement of Coal-Ash Softening Temperature," *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part II, pp. 627 to 636 (1935).

(*b*) *Cone Mold.*—The cone mold shall be suitable for making ash cones $\frac{3}{4}$ in. in height and $\frac{1}{4}$ in. in width at each side of the base, which is an equilateral triangle. A suitable mold, made from metal, is shown in Fig. 8 (the accompanying Fig. 1).

(*c*) *Pyrometer.*[1] — Temperature measurements shall be made with a thermocouple of platinum and platinum-rhodium used in conjunction with a high-resistance millivoltmeter or potentiometer; or with an optical pyrometer of the disappearing filament type, which has been calibrated to be accurate to 10 deg. Cent. up to 1400 C. and to 15 deg. Cent. from 1400 to 1600 C. If a thermocouple is used it shall be protected from the furnace gases by a glazed porcelain tube and so placed in the furnace that the hot junction is in the immediate vicinity of the cones. The pyrometer equipment shall be checked frequently by mounting small pieces of pure gold and nickel in the same manner as the cones. With a strong reducing atmosphere, 1452 C. shall be obtained for the melting point of nickel, and 1063 C. for gold. The pyrometer equipment shall also be standardized from time to time through the temperature range for which it is used, by a suitably equipped standardizing laboratory, such as that of the National Bureau of Standards.

If temperature measurements are made by sighting an optical pyrometer through the glass window of the observation tube the following corrections shall be added to the observed temperatures to correct for absorption of light by the glass window:

OBSERVED TEMPERATURE	CORRECTION TO BE ADDED, DEG. CENT.
800 C.	5
1000 C.	8
1200 C.	10
1400 C.	13
1600 C.	16

28. *Preparation of Ash.*—A 50 to 100-g. portion of the coal or coke sample passing a 250-micron (No. 60) sieve shall be spread out on a 6-in. fireclay roasting dish. The sample shall be completely converted to ash in a muffle furnace at a temperature of 800 to 900 C. A 5 to 10-g. portion of this ash shall be transferred to an agate mortar[2] and ground so that it will pass a 74-micron (No. 200) sieve. The ash shall then be placed in a silica or porcelain capsule, $\frac{5}{8}$ in. in depth and $1\frac{3}{4}$ in. in diameter, and ignited for a period of 2 hr. in a current of oxygen at a temperature of 800 to 850 C. to insure complete and uniform oxidation of the ash.

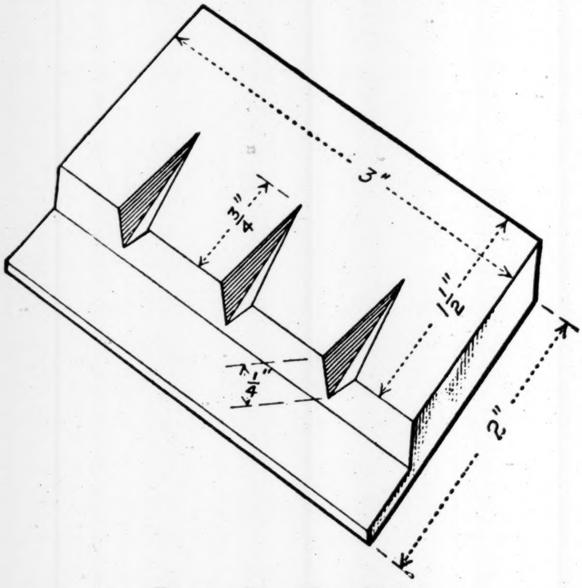

FIG. 1.—Brass Cone Mold.

29. *Preparation of Cones:* (*a*) The ignited ash shall be moistened with a solution of dextrin (10 per cent) containing salicylic acid (0.1 per cent) as a preservative and worked into a plastic mass with a spatula. The plastic material shall be molded into triangular pyramids (cones) $\frac{3}{4}$ in. in height and $\frac{1}{4}$ in. in width at the side of the base. One side of the cone shall be perpendicular to the base. The cones shall be made by firmly pressing the plastic material with a steel

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[1] For detailed information concerning the use of pyrometers see "Pyrometric Practice," U. S. Bureau of Standards *Technologic Paper No. 170* (1921).

[2] A mechanical agate-mortar grinder will save time where many determinations are made.

spatula into a mold of the dimensions specified. A suitable mold is shown in Fig. 8 (the accompanying Fig. 1). The surface of the material shall be struck-off smooth, the cones removed from the mold by applying pressure at the base, and placed in a suitable location to dry.

(*b*) When dry, the cones shall be mounted in a refractory base composed of a mixture of equal parts by weight of kaolin and calcined alumina, or of kaolin and alundum cement, or on a base of refractory brick. In using a mixture of kaolin and calcined alumina or of kaolin and alundum cement, the mixture shall be moistened to make it workable. Part of the mixture shall be spread out on a sheet-iron plate, the cones mounted to not over ¼ in. in depth in vertical positions in small holes made in the base, and the base material pressed into the holes around the bottom of the cones to fill the crevices and to make the cones stand firmly. Usually a number of cones may be mounted in one base as shown in Fig. 9 (the accompanying Fig. 2). When a piece of refractory brick is used as the base, a layer of wet alundum cement about ⅛ in. in thickness shall be spread on the base and the cones pushed down into it.

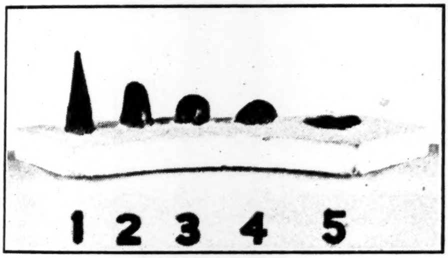

FIG. 2.—Typical Forms of Fused Cones.

(*c*) The mounted cones shall be dried on a hot plate or in a drying oven, and ignited at a dull red heat in an open muffle furnace to remove the carbonaceous material.

30. *Method of Heating:* (*a*) The mounted test cones shall be placed in the furnace at a temperature of not over 800 C. If the furnace temperature is below 800 C., it may be rapidly increased to 800 C., then the rate of heating shall be controlled to give a rate of temperature increase of not less than 5 and not more than 10 deg. Cent. per min. This rate shall be maintained until the end of the test.

(*b*) A reducing atmosphere shall be maintained surrounding the cones during the heating. The ratio by volume of reducing gases to oxidizing gases in this atmosphere shall be between the limits 20 to 80, and 70 to 30 and preferably near the value 40 to 60.[1] Hydrogen, hydrocarbons, and carbon monoxide shall be considered as reducing gases, and oxygen, carbon dioxide, and water vapor shall be considered as oxidizing gases. At least 40 per cent of the reducing gases shall be hydrogen. With gas-fired furnaces so constructed that the combustion gases have free access to the ash cones, the required reducing atmosphere can be maintained by operating the furnace with an excess of gas.

31. *Softening Temperature.*—The softening temperature is defined as the temperature at which the cone has fused down to a spherical lump, as shown in cone 3 of Fig. 9 (the accompanying Fig. 2). Cone 2 has almost reached the softening temperature; cone 4 has passed the softening temperature.

NOTE.—Critical points other than the softening temperature, that may be observed during the test, and which may be of value are as follows:

The Initial Deformation Temperature.—The temperature at which the first rounding or bending of the apex of the cone takes place, as shown in cone 1 of Fig. 9 (the accompanying Fig. 2). Such bending must not be confused with a shrinking or warping of the cone.

The Fluid Temperature.—The temperature at which the cone has spread out over the base in a flat layer, as represented by cone 5 of Fig. 9 (the accompanying Fig. 2).

Tentative revision, submitted June, 1938.

Section 43.—In Part B of this section change the tolerances for volatile matter from their present form: namely,

	Permissible Differences	
	Same Laboratory	Different Laboratories
3. Volatile Matter:		
Bituminous coals	0.5	1.0
Lignites	1.0	2.0
Cokes	0.2	0.4

to read as follows:

3. Volatile Matter:		
Anthracite and coke	0.2	0.4
Semianthracite, bituminous coal, subbituminous coal, and chars	0.5	1.0
Lignite and peat	1.0	2.0

Tentative revision, submitted June, 1937.

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[1] For information concerning the effect of various atmospheres see Bureau of Mines *Bulletin 129* (1918).

Tentative Revision of Standard Method of Sampling Coal (D 21 – 16):[1]

Section 5.—Change the last sentence of the first paragraph of this section to read as follows by the addition of the italicized words:

In the hand method samples of the quantities indicated in Table I shall be crushed so that no pieces of coal and impurities will be greater in any dimension, as judged by eye, than specified for the sample before division into two approximately equal parts. Revision submitted, June, 1937.

Section 6 (c).—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

The laboratory sample [s] shall include [all of one of the quarters, or] all of two opposite quarters (Fig. 34), [as may be required] *and shall not be less than 15 lb. in quantity.* Revision submitted, June, 1937.

Section 7.—Change this section from its present form: namely,

7. Only such mechanical means as will give equally representative samples shall be used in substitution for the hand method of preparation herein standardized.

to read as follows:

7. *Mechanical Preparation.*—(*a*) Gross samples of coal containing pieces $\frac{3}{8}$ in. and larger shall be crushed before dividing so that at least 95 per cent by weight will pass through a 4760-micron (No. 4) sieve and all will pass through a $\frac{3}{8}$-in. round-hole screen.

Gross samples of coal all passing through a $\frac{3}{8}$-in. round-hole screen and less than 95 per cent by weight passing through a 4760-micron (No. 4) sieve may be divided before crushing to not less than 60 lb. as described in Paragraph (*b*) by means of a riffle sampler or its equivalent.

(*b*) The entire gross sample crushed as specified under Paragraph (*a*) shall be reduced in quantity to not less than 30 lb. by passing through a riffle sampler or its equivalent. The riffle sampler shall have openings of not less than $\frac{3}{4}$ in. and not more than 1 in.

(*c*) The sample of not less than 30 lb. obtained as specified under Paragraph (*b*) shall be crushed so that all will pass through a 4760-micron (No. 4) sieve and shall then be divided by passing through a riffle with openings not less than $\frac{1}{2}$ in. and not more than $\frac{3}{4}$ in., obtaining a sample of not less than 15 lb.

(*d*) The sample of not less than 15 lb. which has been crushed to all pass a 4760-micron (No. 4) sieve shall be further crushed so that 95 per cent or more by weight will pass through a 2380-micron (No. 8) sieve. The sample shall then be divided by passing through a riffle sampler with openings not over $\frac{1}{2}$ in., obtaining a sample of not less than $1\frac{3}{4}$ lb. by no more than three passes through the riffle.

It is not practical to crush wet coal to pass a 2380-micron (No. 8) sieve. If the sample of not less than 15 lb., which has been crushed to pass a 4760-micron (No. 4) sieve, appears wet it shall be air-dried before crushing it so that 95 per cent passes through a 2380-micron (No. 8) sieve. However, if the determination of total moisture is of any significance, the entire sample of not less than 15 lb. of wet coal shall be placed in an air-tight container for transmission to the laboratory.

(*e*) The riffle samplers specified in Paragraphs (*b*), (*c*), and (*d*) shall be similar in type to those shown in Fig. 2 (*a*) and (*b*) of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials.

Revision submitted, June, 1937.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

Standard Definitions of Terms Relating to Coal and Coke (D 121 - 30):[1]

The Tentative Definition of the Term Coke (D 121 – 30 T)[2] is intended to be added when adopted to the present Standard Definitions D 121 – 30.

Tentative revision, submitted June, 1921; Modified, 1924, 1926, 1930.

Standard Definitions of Terms Relating to Timber Preservatives (D 324 - 33):[1]

The following definition of the term "water-gas tar" is intended when adopted to be added to the Standard Definitions D 324 – 33:

Water-Gas Tar.—Tar produced in the manufacture of carbureted water gas by the decomposition of petroleum oil by heat in the presence of flue gas.

Tentative revision, submitted June, 1933.

Standard Grain Size Chart for Classification of Steels (E 19 - 33):[1]

The Tentative Grain Size Chart for Classification of Steels (E 19 – 38 T)[3] is in effect a tentative revision of the present Standard E 19 – 33.

Tentative revision, submitted August, 1938.

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[1] 1936 Book of A.S.T.M. Standards, Part II.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 1147 (1930); also 1938 Book of A.S.T.M. Tentative Standards, p. 688.

[3] See p. 1296.

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